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The Blast Furnace and Steel Plant

Vol. XVI PITTSBURGH, PA., AUGUST, 1928 No. 8

BANDS OF STEEL

FROM furnace pours the molten stream
Within whose gurgling mass is read
The epic tale of ages gone,
The tale of human hopes and dread.
What pictures in its murky light
Of struggling men, who toil and curse
That from the hidden depths of earth
May come the gold to fill the purse
Of people yet unborn, their fate
Dependent on these men, who know
That while their anger rises fast
It dies just like the metal's glow.

From roaring vessels pours the flame
That indicates the depths of Hell
Where-in men strove and sweat and died
That steel might serve its purpose well.
The clanging cranes, with seething mass
That, restless, keeps within its bound,
The tugging dinkeys laboring past,
The calls of men, the hissing sound
Of steam escape; from groaning hoist,
The flying sparks, these things they know
And realize that envious dross
But lights the purer metal's flow.

From fiery pit through crashing rolls
That like gigantic hands now hold
The glowing ingot in their grasp,
While back and forth they toss and fold
And knead and roll and squeeze and press
Yea, like a mighty God of old,
Who holds his victim in suspense
The while his gloating tale is told.
The men who strive and strive again
With aching heart or laughing mind
Soon learn to feel that grasping souls,
Like worthless butts, are dropped behind.

By
GEORGE
P.
WARDLEY

The blue gray bands of inert stuff
Through thundering presses seek their goal
Of usefulness to human hands,
To human minds, to human soul;
Their goal of usefulness is won
But in their winning comes the tale
Of grim determined men who knew
The price they paid to never fail.
Stern stuff this steel, but sterner still
Are those who conquered though they wept,
In bands of steel are friendships made;
In bands of steel are friendships kept.

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The Heterogeneity of Steel Ingots*

Although Brief, This Report Concisely Enumerates the Controlling Factors in Ingot Mold Design—An Authoritative Presentation of British Practice

By a COMMITTEE of the
British Iron and Steel Institute†

OF the factors influencing the characteristics of the ingot, the form of mold employed is necessarily one of the most important. It was therefore considered that the presentation of adequate data concerning the design and general details of the molds used would enhance the value of the results of the researches on the ingots themselves. Particulars are now given of some of the molds used for the ingots described in the first report, and for each of these dealt with in the present report; brief details are given in Table I, and dimensioned drawings are given in Figs. 1 to 18.

The paper from which this section is taken is the second report of a committee appointed by the Iron and Steel Institute of Great Britain to investigate the heterogeneity of steel ingots. Other sections of this report will be published in subsequent issues. The first report of this committee was issued in May, 1926. It dealt with steel of the "killed" type.

It is clear that there should be an optimum design of mold for producing any particular steel ingot, and that the design may be influenced by the type and composition of the steel, and by the use to which the ingot is to be put. The optimum design for a given purpose cannot be definitely determined until the phenomena of freezing are more completely understood. The details here given are instructive, however, as indicative of the present "state of the art," and will perhaps assist in the further development of technique. To state in detail the exact functions of the mold is, in the present state of knowledge, almost as difficult and controversial as to attempt to explain the phenomena of the freezing of the ingot. It should, however, be appreciated that the practical development has attained such a standard that ingots can now be produced which are free from many of the defects that were responsible in early days for certain forms of unreliability. This particularly refers to the position of the shrinkage cavity, and the position of the main segregates in the ingot as cast, both of which are largely determined by the design of the mold and the feeder-head. In the first report, only "fully killed" or piping steel was considered, but here steel with other characteristics is also dealt with, and in considering the various ingot molds the type of steel must be kept in mind. Piping steel is necessary for all ingots which are to be made into forgings and into some other forms, particularly where the steel contains special elements. As defects in the ingot may remain in the finished part, the mold is so designed, and also given a feeder-head, to insure that the shrinkage cavity and also the bulk of the segregate shall be in the upper portion which is scrapped.

Material of the Molds

All the molds at present under examination by the committee are made of cast iron, which material meets, to a reasonable degree, the demand as regards physical properties, maintenance, and cheapness. Its low cost, due partly to its ease of manufacture, its comparatively high thermal conductivity, and the fair life of the surface coming repeatedly in contact with the molten steel, coupled with a satisfactory mechanical strength, have proved sufficient justification for the general use of the material. Steel molds are used to some extent, and it is quite realized that further investigation may indicate possibilities of development, for special cases, in the material of the mold. As indicative of the compositions of cast irons used, the following figures, resulting from the analysis of a large mold which had produced 130 ingots, are instructive:

	Per cent
Total carbon	3.70
Graphite	2.91
Manganese	0.42
Silicon	0.98
Sulphur	0.03
Phosphorus	0.026

The macrostructure shown in Fig. 1[9] illustrates, in a general way, the change gradually taking place in the iron at the ingot surface. The type of iron used is invariably that which will cast "grey", and its actual analysis is frequently determined by the desirability of melting up the old molds in the steel-making furnaces which they are serving. Hard or white cast iron is unsuitable, owing to its brittleness, and to its readiness to fracture under stresses resulting from unequal heating, which is a necessary condition of service.

The following values for the physical properties of iron employed for ingot molds are stated for later use in regard to the general problem under consideration:

*An abstract from a paper presented at a meeting of the British Iron and Steel Institute, May, 1928.

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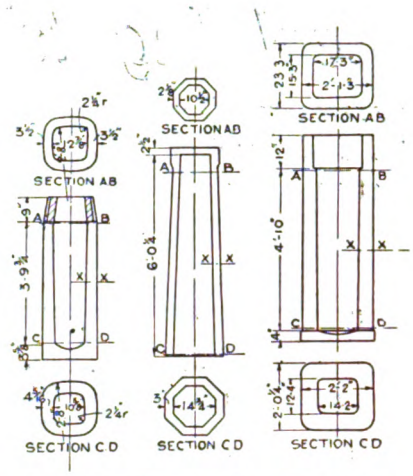

FIG. 1.—Mould A. FIG. 2.—Mould B. FIG. 3.—Mould C.

	Mould A. Lb.	Mould B. Lb.	Mould C. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	121	126	151
Weight of mould per sq. ft. of surface of ingot at XX	178	111	308
	Sq. in.	Sq. in.	Sq. in.
Sectional area of ingot at AB	151	87	264
,, ,, ,, ,, at CD	105	173	168
,, ,, ,, mould at AB	195	89	313
,, ,, ,, ,, at CD	215	176	448
	Cwt. qr. lb.	Ton cwt. qr.	Tons cwt.
Total weight of ingot	15 3 0	1 3 1	1 15
Weight of mould	...	1 1 3	...
Weight of chill portion of ingot	13 1 5	...	1 11
,, ,, ,, ,, ,, mould	18 0 0	...	2 11

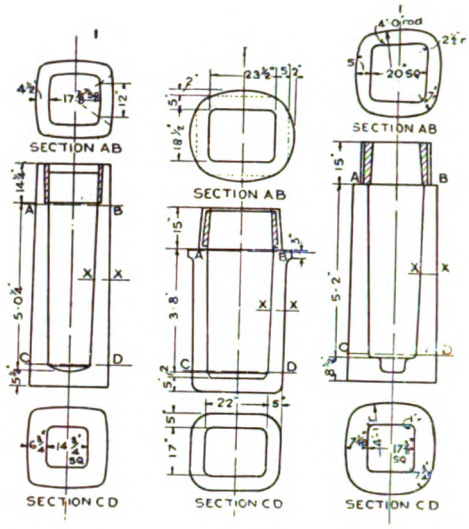

FIG. 4.—Mould D. FIG. 5.—Mould E. FIG. 6.—Mould F.

	Mould D. Lb.	Mould E. Lb.	Mould F. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	159	191	197
Weight of mould per sq. ft. of surface of ingot at XX	286·5	223	263
	Sq. in.	Sq. in.	Sq. in.
Sectional area of ingot at AB	301	427	395
,, ,, ,, ,, at CD	192	366	301
,, ,, ,, mould at AB	396	590	411
,, ,, ,, ,, at CD	557	443	593
	Tons cwt. qr.	Tons cwt. qr.	Tons cwt. qr. lb.
Total weight of ingot	2 4 0	2 16 0	2 17 0 0
Weight of chill portion of ingot	1 16 2	2 0 3	2 7 3 14
,, ,, ,, ,, ,, mould	4 3 0	2 7 3	4 15 0 7

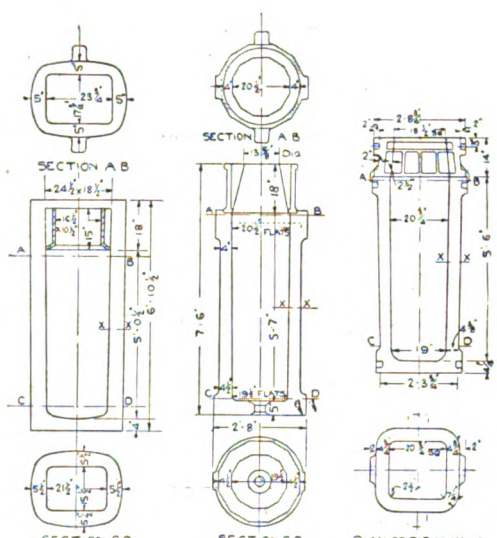

FIG. 7.—Mould G. FIG. 8.—Mould H. FIG. 9.—Mould I.

	Mould G Lb.	Mould H. Lb.	Mould I. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	202	200	206
Weight of mould per sq. ft. of surface of ingot at XX	218	194	204
	Sq. in.	Sq. in.	Sq. in.
Sectional area of ingot at AB	420	340	425
,, ,, ,, ,, at CD	314	304	359
,, ,, ,, mould at AB	403	295	453
,, ,, ,, ,, at CD	394	336	384
	Tons cwt. qr.	Tons cwt.	Tons cwt.
Total weight of ingot	2 18 2	2 18	3 6
Weight of chill portion of ingot	2 11 0	2 11	2 16
,, ,, ,, ,, ,, mould	3 10 0	3 2	3 11

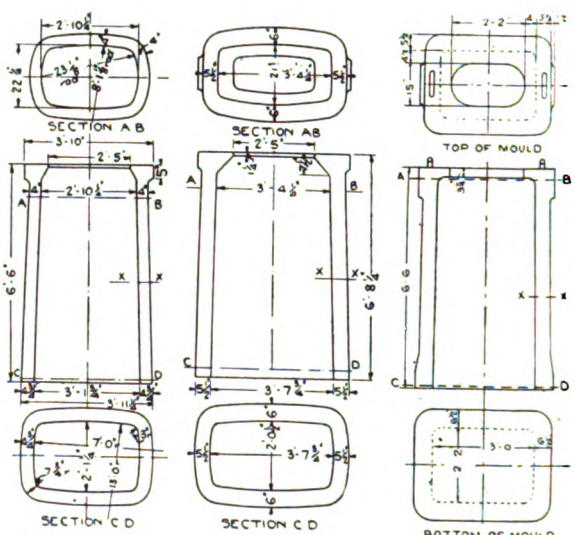

FIG. 10.—Mould J. FIG. 11.—Mould K. FIG. 12.—Mould L.

	Mould J. Lb.	Mould K. Lb.	Mould L. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	301	312	287
Weight of mould per sq. ft. of surface of ingot at XX	206	258	277
	Sq. in.	Sq. in.	Sq. in.
Sectional area of ingot at AB	688	800	808
,, ,, ,, at CD	896	1018	924
,, ,, mould at AB	446	704	731
,, ,, ,, at CD	580	826	945
	Tons cwt.	Tons cwt.	Tons cwt.
Total weight of ingot	6 15	7 15	7 14
Weight of chill portion of ingot	6 15	7 15	7 14
,, ,, ,, ,, ,, mould	5 3	7 11	7 16

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TABLE I—Mold Details.

Fig. No.	Symbol.	Ingot. Total Weight. Tons cwt. qr. lb.	Ingot. Weight in Chill. Tons cwt. qr. lb.	Ingot. Weight of Feeder. Tons cwt. qr. lb.	Mould. Shape.	Purpose.	Weight of Chill. Tons cwt. qr. lb.	Ratio of Weight of Chill to Weight of Steel in Chill. %	Weight of Mould per sq. ft. of Surface at XX. Lb.	Weight of Steel covered by 1 sq. ft. of Mould at XX. Lb.	Ratio of Weight of Mould to Weight of Steel. %	Ingot Example Number.
1	*A*	0 15 3 0	0 13 1 5	0 2 1 23	Square	Alloy steel	0 18 0 0	135	178	121	147	17
2	*B*	1 3 1 0	1 3 1 0	...	Octagonal	Rly. carbon steel	1 1 3 0	93	111	126	89	32
3	*C*	1 15 0 0	1 11 0 0	0 4 0 0	Square	Alloy steel	2 11 0 0	164	308	151	204	...
4	*D*	2 4 0 0	1 16 2 0	0 7 2 0	Square	Alloy steel	4 3 0 0	227	286·5	159	180	19 & 20
5	*E*	2 16 0 0	2 0 3 0	0 15 1 0	Rectangular	Rly. carbon steel	2 7 3 0	117	223	191	116	4 [1]
6	*F*	2 17 0 0	2 7 3 14	0 9 0 14	Square	Alloy steel	4 15 0 7	198	263	197	133	18
7	*G*	2 18 2 0	2 11 0 0	0 7 2 0	Rectangular	Plate steel	3 10 0 0	137	218	202	108	5 [1]
8	*H*	2 18 0 0	2 11 0 0	0 7 0 0	Twelve-sided	Carbon steel	3 2 0 0	121	194	200	97	6 [1]
9	*I*	3 6 0 0	2 16 0 0	0 10 0 0	Square	Billet steel	3 11 0 0	127	204	206	...	29
10	*J*	6 15 0 0	6 15 0 0	...	Rectangular	Plate steel	5 3 0 0	76	206	301	68	25 & 27
11	*K*	7 15 0 0	7 15 0 0	...	Rectangular	Plate steel	7 11 0 0	97	258	312	82	26
12	*L*	7 14 0 0	7 14 0 0	...	Rectangular	Plate steel	7 16 0 0	101	277	287	...	30 & 31
13	*M*	8 0 0 0	8 0 0 0	...	Rectangular	Plate steel	...	...	258	303	85	8 [1] & 28
14	*N*	9 7 3 0	8 1 0 0	1 6 3 0	Octagonal	Alloy steel	9 3 0 0	126	392	347	113	...
15	*O*	17 12 0 0	15 7 0 0	2 5 0 0	Octagonal	Alloy steel	18 9 0 0	120	377	315	119	11 [1]
16	*P*	25 0 0 0	18 15 0 0	6 5 0 0	Octagonal	Alloy steel	17 15 0 0	94	408	414	98	12 [1]
17	*Q*	50 3 0 0	40 8 0 0	9 15 0 0	Round	Alloy steel	41 4 0 0	101	...	...	...	22
18	*R*	119 10 0 0	96 10 0 0	23 0 0 0	Octagonal	Alloy steel	64 2 0 0	66	...	...	...	23

[1] See First Report, *Journal of the Iron and Steel Institute*, 1926, No. I. pp. 48–77.

p = specific gravity = 7.2.

s = specific heat = 0.125 cal. per grm.

k = thermal conductivity = 0.11 cal. per sq. cm. per °C. per cm.

h = coefficient of radiation (according to Newton's law of cooling) = 9×10^{-4} cals. per °C. per sq. cm. (at 300° C.).

Some of these data can well be amplified, especially as to their values at high temperatures.

Functions Performed by the Mold

Primarily, the function of an ingot mold is to provide a receptacle for the molten steel, which shall, after freezing, be in a form suitable for subsequent working. A further function of the mold is to abstract heat from the molten steel, and to dissipate it by radiation, or other means, from its outer surfaces. The mold abstracts heat from the steel by two not entirely independent methods. The first is the chilling action, due to the mold being at a much lower temperature than the steel in it, and acting as a receptacle into which the heat is emptied from the steel. The second, which becomes the more vital as the cooling proceeds, is the outward passage of heat by conduction through the walls of the mold, with subsequent radiation from its outer surfaces. These two effects are very important and will be further discussed.

The above are the essential functions of an ingot mold, but it has necessarily become more and more the practice so to design the mold that it may fulfill the further function of producing sound ingots free from cavity with the harmful influence of the segregation phenomena reduced to a minimum. The form of the ingot mold should also be such that the amount of steel to be discarded from the ingot may be as small as possible.

Characteristics of Representative Molds

A brief survey of the designs of molds employed for the ingots under discussion is useful at this stage. The molds A, C, D, and F are those used for producing the smaller alloy steel ingots. They all have superimposed refractory-lined feeder-heads, the walls of the mold are suitably increased in thickness towards the bottom, and the cross-section of the ingot is greater at the top than at the bottom. At the position XX, half-way down the chill portion of the ingot, a square foot of the mold covers much less than its own weight of liquid steel, the percentage relationship of the weight of the mold to the steel being of the order of 133 to 204 per cent. This decreases upwards and increases downwards, thus insuring that the freezing of the steel is less rapid as the mold is ascended. The molds N, O, P, Q, and R are those used for the larger forging and alloy steel ingots, and in general principles will be seen to conform with the smaller molds just discussed. They all have refractory-lined feeder-heads, and are larger in internal section at the top than at the bottom. Although the walls of the mold do not increase in thickness down the chill, still in every case the local ratio of weight of mold to the quota of steel which it covers increases down the ingot owing to the decreasing sectional area of the ingot. At the position XX, the percentage weight of the mold to the steel in these larger ingots is of the order of 98 to 119 per cent.

Molds E, G, H and I are used for carbon steels.

Molds J, K, L and M are of particular interest, being the molds used in casting ingots from non-piping steel. No feeder-head is provided, and the ingots are usually heavier in section towards the bottom than towards the top. The mold walls are practically of uniform thickness and partially form a chill top. At the position XX the weight of mold covering its quota of steel is much less than that of the steel, the relationship being of the order of 68 to 85 per cent, which is considerably less than is the case with the other type of molds, particularly the smaller sizes.

Mold B is included as an example of molds used in large quantities years ago when ease of manipula-

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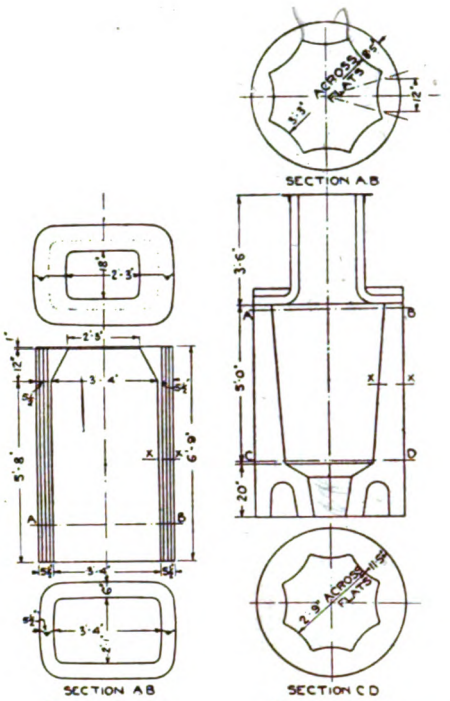

FIG. 13.—Mould M.

FIG. 14.—Mould N.

	Mould M. Lb.	Mould N. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	303	347
Weight of mould per sq. ft. of surface of ingot at XX	258	392
	Sq. in.	Sq. in.
Sectional area of ingot at AB	938	1296
,, ,, ,, at CD	...	915
,, ,, mould at AB	818	1130
,, ,, ,, at CD	...	1437
	Tons.	Tons cwt. qr.
Total weight of ingot	8	9 7 2
Weight of chill portion of ingot	...	8 1 0
,, ,, ,, ,, ,, mould	...	9 3 0
Percentage weight of head	..	20%

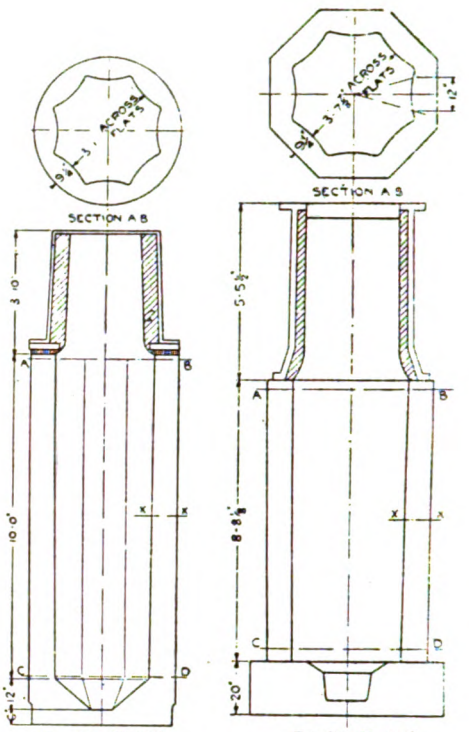

FIG. 15.—Mould O.

FIG. 16.—Mould P.

	Mould O. Lb.	Mould P. Lb.
Weight of steel covered by 1 sq. ft. of mould at XX	315	414
Weight of mould per sq. ft. of surface of ingot at XX	377	408
	Sq. in.	Sq. in.
Sectional area of ingot at AB	1155	1606
,, ,, ,, at CD	1033	1383
,, ,, mould at AB	1264	1543
,, ,, ,, at CD	1386	1481
	Tons cwt.	Tons cwt.
Total weight of ingot	17 12	25 0
Weight of chill portion of ingot	15 7	18 15
,, ,, ,, ,, ,, mould	18 9	17 15

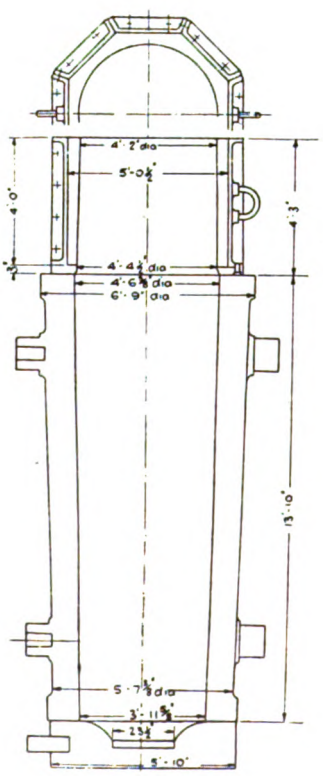

FIG. 17.—Mould Q.

	Tons	cwt.
Total weight of ingot	50	3
Weight of chill portion of ingot	40	8
,, ,, ,, ,, ,, mould	41	4

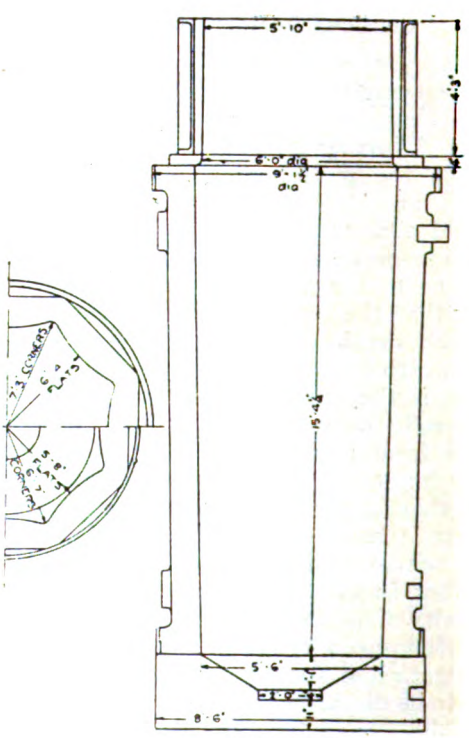

FIG. 18.—Mould R.

	Tons	cwt.
Total weight of ingot	119	10
Weight of chill portion of ingot	96	10
,, ,, ,, ,, ,, mould	64	3

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tion was placed before quality of product; the reason for discarding such a form of mold was not so well appreciated then as now.

Considerations in the Design of Molds

Any factor which influences the functioning of the mold as above discussed is of importance in estimating its weight and dimensions. Such factors are numerous and are not confined to the properties of the mold itself, but are inherent also in the steel inside the mold. Economic factors also enter, in that it may be advisable in some cases to sacrifice the advantages of using a certain shape of mold in order to simplify and considerably reduce the cost of the subsequent working of the steel ingot. The relative importance of many of these factors, too, is not very definite, so that it is often extremely difficult to decide a priori which of two ingot molds is the better for a particular purpose. It is only possible to enumerate the various factors which operate, and the direction in which they act, and then perhaps, from a general review, arrive at conclusions.

In the design of the shape of the mold, five points concerning the ingot must be borne in mind:

(a) Freedom from cavity.
(b) Suitability for and ease of further working.
(c) The stresses set up on cooling.
(d) The elimination, if possible, of planes of weakness.
(e) The layout of the segregate.

The freedom from cavity depends on the supply of sufficient molten material to fill up the spaces produced by contraction, and the prevention of isolated lakes of molten material. The former is controlled by the design of the feeder-head, and does not concern the mold itself. The latter is influenced by the relative rates of cooling of the various portions of the ingot, the change in dimensions on freezing, and the coefficients of expansion of both the solid and molten materials, and the design of the mold. Ingots with the narrow end at the top are most likely to produce these isolated lakes; ingots with the wide end at the top reduce this possibility. The correct taper is difficult to decide, as it depends on the rates of cooling at the freezing temperature in the various parts of the ingot. The taper should be such as to make possible efficient feeding of the body of the ingot.

The phenomenon of segregation depends not only on the chemical composition of the steel in the ingot, but also on the rate of cooling, both of the ingot as a whole, and of each individual point in the ingot. For example, and referring more particularly to piped ingots, near the walls of the ingot, where the rate of cooling is rapid, the segregated impurities are trapped in the rapidly growing crystals. Further inside the ingot, where the cooling is slower, the segregates will collect together and produce the so-called ghosts, or they may tend to rise to the surface and collect in the scrapped ingot head. Of importance also are, naturally, the thermal conductivity, density, and specific heat, which are all more or less affected by the chemical composition of the steel.

Dependence of the Rate of Cooling Upon the Characteristics of the Steel and of the Mold

The thermal conductivity of the ingot material, its specific heat and density, affect the rate at which heat can be extracted from the center of the ingot. The greater the value of

$$k/ps \quad (k = \text{thermal conductivity}, p = \text{density}; s = \text{specific heat}),$$

the smaller will be the temperature gradient in the ingot at any particular place at a certain time after casting, and the lower will be the temperature at that place. The rate of cooling at any particular place, when it has reached a certain temperature (say, freezing temperature), will also be proportional to this expression, other things being equal. Apart from determining the internal dimensions of the mold, the coefficient of expansion has a secondary influence; the greater total contraction of the ingot material, as compared with the ingot mold, causes the former to separate from the latter, leaving a space between the two. The influence of this upon the rate of cooling

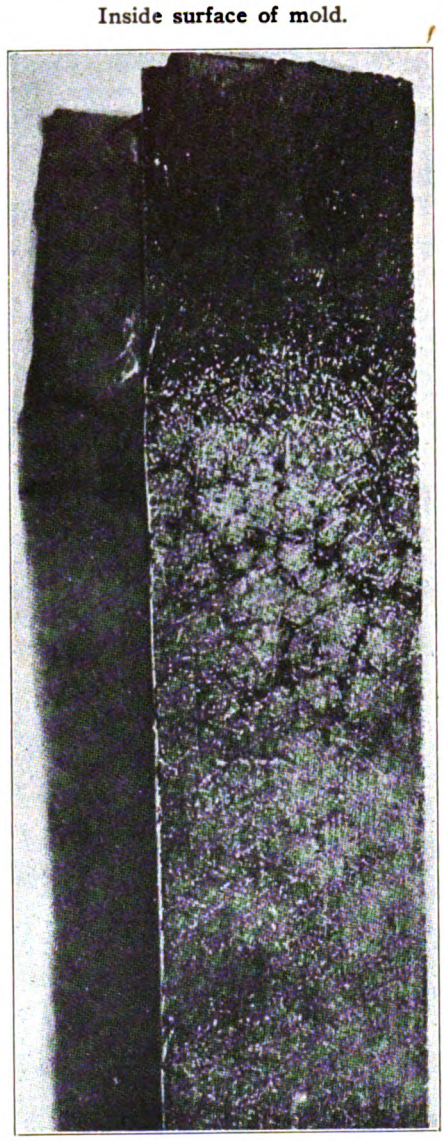

FIG. 19—Macrostructure of used ingot mold showing decarburization of the inner surface extending to same depth.

is somewhat doubtful, but it is probable that the greater portion of the heat will be transferred by radiation, so that the effect is of little significance. The amount of the initial chilling action of the mold will depend on the relative specific heats of the ingot

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and mold materials. As, however, the specific heats of all ferrous materials are very much the same, the differences produced by variations in this factor may be neglected in this connection.

For molds of the same dimensions, the greater the conductivity, the greater will be the rate of cooling. The thickness of the mold walls affects the amount of the chilling effect of the mold, which increases with increasing thickness. Owing to the finiteness of the conductivity of the materials, however, the increase will not be proportional, but will tend to a limiting value. In the later stages, the rate of cooling of the ingot will be reduced by the increased thickness.

Planes of Weakness in the Ingot

Planes of weakness are caused where the crystals growing from two faces meet. They are bound to occur in those portions of the ingot where the freezing produces columnar crystals. Therefore, the closer the internal shape of the mold conforms to that of a cylinder, the less will be their effect. Circular ingots, especially in the larger sizes, however, are prone to stress cracks. Octagonal or hexagonal molds have actually proved better for the larger ingots; except in the earliest stages, they freeze internally in very much the same way as they would in a cylindrical mold.

Stresses in the Ingot Due to Cooling

Owing to the difference in the rates of cooling of the outside and inside of the ingot, stresses are invariably set up in the cooling ingot, and they may be of such magnitude as to lead to cracks. These stresses increase with an increase in the temperature gradient across the section, and vary with different types of steel. The design of the mold, therefore, both in shape and dimensions, must be such as to reduce this temperature gradient as much as possible, bearing in mind the other features of the ingot. In this respect the position and magnitude of the change points, if any, in the steel are of importance. The lower the temperature at which they occur, and the greater their magnitude, the greater will be the stresses produced. There are other factors which influence the rate of cooling of the ingot and, hence, the design of the ingot mold—for example, the temperature of the outside atmosphere and the rate of radiation from the walls of the mold, but as the variations in these are small, they may be taken to be constants.

As regards the stresses and planes of weakness, as the ingot cools the outside tends to contract at a greater rate than the inside, at any rate during the earlier stages, while the temperature gradient is changing. Tensile stresses are therefore set up in the periphery, and may be sufficient to produce cracks there. Later on, when the outside has become comparatively cold and the inside is still cooling, the nature of the stresses is reversed. The tensile stresses are then present in the middle of the ingot. The magnitude of the stresses depends on the relative rates of cooling of the inside and outside of the ingot. A thick mold might, therefore, be expected to increase the stresses in the early stages, but later on it would cause a slower and more uniform rate of cooling throughout the ingot, which would tend to decrease the stresses. Stresses, too, are produced by the passage of various parts of an ingot through the critical ranges at different times. Many factors enter here, such as the temperature distribution and the influence of the rate of cooling on the actual temperatures of the transformations. These are determined by the chemical composition, which also influences the magnitude of the changes that occur along with them.

Necessary Empiricism in Design

Such, then, are some of the factors which must be taken into account in determining the weight and dimensions of an ingot mold. A mathematical treatment of the subject is extremely difficult, and solutions can only be obtained, even in the most simple cases, by neglecting various terms, such as variations in the physical properties with temperature, latent heats of fusion, and other critical thermal changes, etc. Even when simplified in this way, the mathematical expressions arrived at are intricate, and can only be solved with difficulty by graphical methods. Apart from these mathematical difficulties, in order correctly to design an ingot mold, bearing in mind the factors enumerated above, one must first be satisfied as to the best rate of cooling and temperature gradient across the ingot, especially at the period when the material is at the point of freezing. It will naturally vary at various places in the ingot. Further, the best rate of cooling may be different for different steels. In other words, the design of the mold will depend on what is desired in the finished ingot. If an ingot be required in which the amount of columnar crystals is to be as large as possible, then the thicknesses of the walls should be adequate. Without knowing, however, the rates of cooling which give rise to the formation of the columnar crystals, the thickness of mold wall cannot be predicted. It would appear that the limiting depth of these crystals is already reached with fairly thin walls, so that any increase in thickness of mold wall beyond this has very little effect. It has been suggested that the influence of varying thickness of mold may be divided into three stages: 1—The initial stage, in which there is the sudden drop in temperature at the outer surface of the ingot, due to the chilling action of the mold; 2—an intermediate condition, when the mold has become heated and there is a more or less gradual change in the temperature at the interface between ingot and mold; 3—the final stage, when the ingot and mold cool together, almost as if they had become one integral mass—that is to say, when the mold has practically lost its initial function as a receptacle of heat and become simply a conductor. The thickness of the mold will operate in different directions in the three stages, between which there is, of course, no sharp division. At the commencement of the first stage—that is, as soon as the liquid is poured into the mold—the outer skin of the ingot and the inner skin of the mold rapidly approach the same temperature. This temperature is independent of the thickness of the mold, and is determined mainly by the initial temperatures of the steel as cast and the mold.

Conclusion

It appears that even if a complete mathematical expression could be given to represent the freezing of the ingot in the mold, there would still be considerable doubt as to how to apply it, until agreement is attained as to the best crystalline arrangement to aim for, and even then the influence of the rate of cooling, or of the velocity of freezing across the section, on that crystalline arrangement must be known.

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British and American Automotive Steels

Comparison of Heat Treating Methods Are Given, and Reasons for Use of Super-Steels Reviewed—The Air Hardening Nickel Chrome Series Coming Into Use—Heavy and Light Engines

By J. W. URQUHART*

PART II

IF the heat treatment methods followed by the Ford organization may be accepted as being fairly representative of American practice along a line of automobile building embracing cars of a particular class, it may be worth while to offer some comment upon the processes followed and the ultimate effect of them upon the efficiency and "life" of the car.

Reference to the capital letter or letters designating each type of steel, analysis of which was set forth in the table of constituents already given, will afford a guide as to the suitability of the procedure followed in each case.

The "A" Steel

We have here essentially a high grade carburized product, somewhat of greater shock-resisting strength than has hitherto been common in European practice. The chief point of difference lies in the inclusion of both chromium and vanadium in the composition of the steel, mainly the latter.

This particular product is used in the construction of a very important part of the transmission, namely, the main driving pinion, and must be both hard (about 500 Brinell) and tough—a maximum hardness of the surfaces of the teeth and a similar tenacity of toughness in the body of the part. It is not stated that, before this pinion is machined, it shall receive a thorough anneal, this being regarded as essential in European practice. But it is normalized for 1½ hours (air cooled). The carburizing temperature (maximum, 1750 deg. F.) is quite the usual heat, but the time the part is held in the carburent is only 6 hours, giving a depth of martensite of 1/32 to 3/64 in.

In European work the part would be permitted to cool out in the carburizing mixture, before reheating for final quenching. Instead, it is withdrawn and immersed in the cyanide bath for 8 minutes, then quenched in oil. It is finally drawn for 1 hour in oil of 400 deg. temperature, the hardness being given as 255 to 340 Brinell, and 75 to 85 scleroscope.

The writer prefers to cool out in the box; reheat (without cyanide) in open furnace (reducing atmosphere) to 1750 deg. F., quench in cold oil, transferring while still hot to the drawing oil of some 400 deg. F. for the hour, final cooling being in a warm place.

There is no doubt that, for use by unskilled heat treaters, the cyanide bath is a great convenience, but it is apt to give a fallacious reading upon taking a Brinell or scleroscope hardness test. This is owing to the fact that all of the fusible cyanogen compounds produce, at the appropriate temperature, followed by quenching, an exceedingly thin layer of hardness, concealing, to some extent, the real condition of the steel throughout a depth of 1/32 in. If the pinion in question is to be finished by a "polishing grind," as many high grade toothed wheels now are, the objection to the cyanide treatment does not apply.

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It is questionable whether the free use of cyanide will not soon be prohibited. The substance itself is poisonous, and its fume is deadly. Very effective draft hooding has to be provided over the bath, but it is difficult to avoid getting the salt upon the hands and utensils. There are other salts to which these objections do not apply, and they may be made equally effective in raising the temperature without the risks of incipient scaling, which appear to be the main objective in using cyanides in the automobile heat treating industry.

The "AA" Steel

An equally important line of parts, in which the fullest attainable tensile strength must be attained—crank shaft, connecting rod, drive shaft and front axle swivel—is produced from the above grade of steel: Carbon 0.26-0.32, manganese 0.65-0.80 per cent.

Let us follow the heat treatment of one of these important parts—the crankshaft. After forging, it is treated before machining, being heated in cyanide bath for 1 hour at 1650 deg. F., cooled in air, reheated to 1500 deg. F. and held for 1½ hours and then quenched in soap solution or soluble oil mixture. It is removed from quench at 400-600 deg. F. and annealed at 980 deg. F. for 2½ hours, Brinell hardness to be 286-321. Some of this data has already appeared in the schedule covering this part, and is repeated here for convenience of comment.

Since the whole of the above treatment is carried out prior to any preparation being made for the lathe work upon the shaft, the writer sees no reason whatever for cyaniding the part, either for first or second treatment, except that it may, in this particular plant, be an economical feature of the cost of the shaft; an apparent advantage that would surely be offset by the greater difficulty of turning off the outer skin of the rough forging due to the influence of the cyanide. In Europe, the shaft would be brought up to the required temperatures in the oven furnace, which, for this particular part, need not be provided with a reducing atmosphere or other refinement, except temperature certification.

Comparisons of treatment as between the work of the above plant and that common in Europe are difficult, owing to the fact that the composition of the steels used is seldom identical. For example, it is seldom that crankshafts are manufactured in England without the use of the nickel steels, which are here more in favor for such parts than the manganese-chrome steels used by the Ford organization, as scheduled in the table.

In the table of the nickel-chrome steels already given will be found the material in general use for the production of the more highly stressed parts of automobiles, the 2 to 3½ per cent nickel steel being very generally in favor for crankshaft and transmission gear. The carbon percentage varies between 0.15

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and 0.30, manganese, 0.30 to 0.60, chromium, 1.00 In the annealed condition this steel has an elastic limit of 22½ tons, and in the heat treated condition—not fully attained in pieces like crankshafts—of 60 tons per sq. in. In the case of parts that do not call for machining after full heat treatment, this high figure of tensile strength can be relied upon.

The Heat Treating of Crankshafts

The above part is the most difficult of all the components of the chassis to get through the fullest heat treatment without trouble. Practically it amounts to this, that some sacrifice of tensile strength must be conceded if a deal of "corrective" or trueing up treatment is to be averted. In other words, it is not a profitable proposition to produce an extremely hard dead true crankshaft, owing to distortion produced by heat and fixed by quenching. The shape and run of the grain or fibre of the steel accounts for this difficulty.

Instead of insisting upon a maximum possible tensile figure in this part, it is found more practicable to carry out all of the important work of heat treating upon it before it is machined. The high speed steels of today can handle a very hard grade of nickel-chrome steel, without difficulty, so long as the cuts taken are of reasonable depth. Shafts produced in this way can be relied upon for freedom from twist and for general stiffness.

Furthermore, a high degree of heat treatment can be imparted to crankshafts when the finishing touches of the turning phase can be conducted in the grinder, capable of reducing the hardest steel commonly produced. It is true that this adds to the cost of the shaft in several ways, the necessarily high allowance of material being one of the contributory causes.

The Differential Gear Steels Used

The material and treatment already commented upon cover most of the highly stressed components, if we expect the driving gear of the differential case and the triple gear transmission components connected therewith. The steel chosen is designated "AAA," of the composition, carbon 0.30-0.35, manganese 0.65-0.80, chromium 0.90 -1.10 per cent, and is intended to be of somewhat higher tensile strength than either of the two preceding grades of material. The increase in the percentage of both carbon and chromium will insure this. Hence, it is a harder steel throughout its mass, and is well calculated to stand up to the heavy work of the differential as a whole.

The treatment specified for the driving gear by itself is—before machining, the forging is heated up for 1 hour to 1560 deg. F., and then left to soak for 15 minutes, cooling slowly. The Brinell hardness is then 170-207. Treatment after machining is: heat up in cyanide at 1500 deg. F.; soak for 7 minutes; quench in oil; draw in oil at 400 deg. F. for 1 hour, when the hardness should register 387-512.

The triple gear is also from forgings, which are heated up to 1560 deg. F. and cooled slowly; after machining, heated to 1500 deg. F. and soaked for 10 minutes in cyanide at that temperature, quenching in oil at 400 deg. F., holding the drawing heat for 1 hour in the same oil. The hardness number should now be 387-477.

It is to be assumed that in first heating the above kind of forgings for strain relieving and annealing, or for merely normalizing, the cyanide bath is not employed. It is also to be assumed that the temperature regulation of the oven furnace used is sufficiently precise to render unnecessary the recourse to the salt bath. Judging from the impressions conveyed by the above directions, it is difficult to find a reason for the use of cyanide at all, unless its main function is the protection of the machined surfaces, since its "hardening" power, being skin deep, is negligible, in treating automobile components of the above kind; but this slight hardening effect of cyanide is very apt to give a false hardness indication by Brinell or even by diamond-point hardness indicating machines. It is usual, therefore, to expose, by grinding, the true surface of the steel before taking a fiducial reading after cyanide heating and quenching.

Some Steels Used for Corresponding Parts in European Practice

The great variety of alloy steels used in European auto-chassis work, some of the most costly of them being sometimes used in making quite cheap cars, renders the making of a fair comparison between the material above discussed very difficult.

Reverting to a consideration of the table of some of the automobile steels given in the first part of this article, a few of the main uses of the various grades are there briefly touched upon.

All of the line of steels designated by Fords by the letters G, H, E, and EE would be regarded as plain carbon steels by European engineers, differing only in the degree of hardness attainable after treatment. None of these steels carries a percentage of chromium, and only the two last a rather high percentage of manganese. The depth-hardening effect of the manganese constituent is well recognized, and it is probably for this reason that the organization in question uses this inexpensive type of steel for the front axle, spring perch, fender supports, transmission pedals, drive shaft sleeve, clutch plates, drive shaft roller bearing housing, and so on, many of which are carburized as a finishing phase, to afford a surface hardness for various reasons. All of the above steels make good carburizing material, especially those with a low percentage of self-carbon.

If it is desired to have a fair idea of the kinds of steel that are in most favor for the above purposes in Europe, attention may be directed to the line of 1.5 to 3½ per cent nickel steels set forth in the table already given.

These are generally known as nickel-chromium steels. Their great superiority over the plain carbon steels, after appropriate heat treatment, is leading to the gradual abandonment of the earlier type for the construction of all such parts as are included in the schedule of various parts just mentioned. It is evident, however, that the Ford concern have found their line of carbon steels to yield excellent service. If there will arise a reason why this line of carbon-manganese steels may be abandoned in favor of the nickel-chromium series, it will not be difficult to find an explanation for the change. If we turn to the test figures, we will see that a carbon steel forging, heat treated and quenched in water can be made to show a yield point of 24.8 tons, and bear a maximum load of 39.5 tons per square inch, with elongation 20 per cent on 2 in., the Izod impact figure in foot-pounds being 15.

Compare these figures with those given by 2 per cent nickel, medium low chromium steel, when oil quenched and tempered at 600 deg. C. Here we have a yield point of 40 tons, a maximum load of 40-45 tons,

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elongation per cent on 2 in. 25, with an Izod impact figure of 50 ft.-lbs.

The ultimate effect of these facts, bearing upon the tensile strength of the two kinds of steel is that all of the parts made from the nickel-chromium steel may be of much lighter section—in other words, a chassis made in this steel will weigh very much less than one made from carbon steel. As the art of building automobiles is a progressive one, the change from one steel to the other is inevitable. It is true that the superior steel costs more, but when it is considered that less of it is required (all parts being of lighter section for equal strength) to attain the same end, it will be agreed that the comparison of relative costs is an argument of little weight. Correct heat treatment, is, however, required to bring out the potential strength of the nickel-chrome steels, for it is well known that a carbon steel untreated is almost equal to a nickel-chrome steel in the same condition.

Some Air Hardening Automobile Steels

Under the designation of air hardening nickel-chrome steel we have a material now coming into general use in the automobile industry. Its service is at present mostly reserved for the making of the highest class of heavy duty gears, transmission gear and very highly stressed parts in general. As for its use in the making of crankshafts, there are at present certain difficulties incidental to the heat treatment that have delayed its general adoption. The very high impact value of this material, figures of which are given in the table (Section I of this article) are so striking that they will be repeated here. Taking the best type of the Ford carbon-manganese series, the Izod impact value is computed at the figure 16. This value has to be compared with the Izod impact value of 35 for the air hardened nickel chrome material. It will be noted that the yield point of the tempered specimen is 45 tons; the maximum load 55-65 tons per sq. in.; elongation per cent on 2 in. 15; reduction of area per cent 45.

One of the great advantages of the air hardening nickel-chrome series is its immunity from the risks of quench, cracks, and quench-warping common to all of the carbon steels. In the heat treatment the critical range of these steels is in the neighborhood of 1360 deg. F. Air cooling may be conducted from any figure slightly exceeding this temperature. Excess temperature should be avoided, as inducing crystal growth. The consequent increased crystal growth due to excessive temperature cannot be corrected by subsequent tempering.

Most of the air-hardening steels are martensitic after cooling slowly in air. Their impact-resisting properties are considerably improved, without material loss of hardness, and no change in the microstructure by tempering at 392 deg. F. If the temperature is raised to 1112 deg. F. the steel becomes sorbitic, and exhibits in this condition, properties similar to those of oil-hardened and tempered nickel-chrome steels of much lower chromium content. The air hardening steels may therefore be regarded to some extent as almost a general purpose material, according to its heat treatment.

Weight and Bulk vs. Tensile Strength

There are certain lines of engineering construction, in which the utmost attainable static and dynamic strength of the steels employed will always enable machines so built to attain precedence of both performance and endurance. Two of these kinds of machines are outstanding instances—the automobile and the aeroplane. The building of a great bridge or even a great stationary engine, permits of great latitude in the matters of bulk and consequential strength, but in auto-chassis work the utmost dynamic resistance that can be attained per pound weight of steel may be regarded as the basic requirement. Hence, the main cause underlying the rapid development of what are sometimes called the super steels, in the past decade.

It is in reference to this important matter that the various testing results outlined in the preceding table will be found most informative. Their understanding and computation are comparatively simple. It being a basic principle that the working stress shall not exceed, or even nearly approach, the elastic limit of the material, it remains to compute the extent of the tensional and torsional stress to which the steel will be subjected in actual service. In the particular matter of the automobile, the impact value of the steel will, for many points of the chassis, be of the utmost importance, the normal work of the machine consisting largely of sudden impact shocks and torsions. The crankshaft and the front axle are good examples of parts normally under severe shock service.

Material of relatively low tensile strength can, of course, be piled into the parts so stressed, and this is what is sometimes done in the case of cars sold at a low price. There may be an ample margin of safety, and no fracture may ever occur, but this extra weight and bulk has to be carried throughout the life of the car, at a great sacrifice of liveliness and unnecessary cost of petrol. The continuous waste even extends to the tires and the patience of the owner.

Battle of the Big and Little Engines

It is with some diffidence that an engineer of a friendly nation approaches the above matter, for the big, powerful (sometimes "wooley") engine of a car such as the Ford organization has for over a decade been sending to Europe has, strangely enough, been the cause of a most intensive campaign in England to equal its performance, by means of engines of perhaps half its weight and bulk, largely dependent upon the use of the "super" steels. It was, of course, the Chancellor of the Exchequer that, supported by the Road board, compelled the chassis builder to engine his production with a motor of small dimensions, since a heavy tax was levied upon every inch in the diametral measurement of the cylinder, and is in force to this day.

In order, then to produce a source of power that could equal the performance of the "wooley" engine, and yet be of such moderate cylinder capacity as to carry a small load of taxation, necessity compelled the production of a power unit meeting these two requirements. This is a singular instance of high engineering efficiency being fostered directly by taxation—otherwise perhaps an impossible result.

It must be conceded that part of the high efficiency of engines built to meet taxation of this kind must, in the nature of things engineering, run at a high rate of speed. A high speed engine, then, had to lead to equally efficient transmission gearing, involving the employment of the most highly resistant kinds of steel. These facts must be regarded as the main reason why the fully heat-treated steels of the highest dynamic endurance have been in such extensive demand in the English automobile industry, years before their use might otherwise have become general.

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Methods of Cleaning Blast-Furnace Gas*

A Comparison of Twelve Important Installations Using Various Methods—Results Tabulated to Show the Performance and the Operating Costs as Well

By V. HARBORD†

PART II

PLANT IX, Halberg-Beth Filtration Plant, is treating approximately 2,000,000 cu. ft. of gas per hour, containing about 3 to 4 grm. of dust per cu. m. The gas first enters the towers in which it is air-cooled to a temperature of 75 to 100 deg. C. (water being added if necessary) in order to prevent the burning of the bags and to deposit moisture; it is then reheated to 80 to 120 deg. C., so that it will pass through the bag house without the temperature dropping below the dew point. The temperature control is most important in these plants.

PLANT IX—Halberg-Beth Gas Cleaning Plant, 1926-1927.

Date. Week Ending.	Total Volume of Gas Cleaned (N.T.P.).	Filter Bags Changed.	Total Dust taken out in Filtration.	Dust taken out (N.T.P.). Grm. per cu. m.	Dust Content of Clean Gas[1] (N.T.P.). Grm. per cu. m.	Kw. per Million cu. ft. Gas Cleaned (N.T.P.).
1926.	1000 cu. ft.		Tons. Cwt.			
Jan. 9	306,181	15	30 12	3·60	0·002	80·4
,, 16	301,102	11	41 19	5·28	0·003	81·0
,, 23	307,378	5	38 10	4·73	0·003	71·1
,, 30	319,254	4	47 3	5·30	0·004	81·3
Feb. 6	318,207	6	36 10	4·00	0·0045	84·8
,, 13	320,906	10	35 13	3·83	0·004	83·8
,, 20	320,726	20	37 16	4·10	0·003	85·5
,, 27	328,201	23	33 0	3·23	0·004	85·1
Mar. 6	355,972	26	33 9	3·37	0·0025	76·9
,, 13	365,782	16	31 7	3·07	0·003	72·7
,, 20	391,809	16	32 12	3·00	0·004	73·0
,, 27	388,878	6	32 12	3·01	0·002	71·3
Apr. 3	367,186	8	42 10	4·15	0·003	72·2
,, 10	378,911	4	41 12	3·94	0·003	73·1
,, 17	392,849	11	33 13	3·08	0·005	74·8
,, 24	394,800	10	34 9	3·12	0·004	72·0
May 1	376,000	6	35 3	3·40	0·004	78·0
1927.						
Jan. 8	95,814	2	4 10	1·68	No analysis	78·0
,, 15	247,707	7	16 18	2·70	,,	74·0
,, 22	256,747	8	31 9	4·41	,,	85·0
,, 29	353,163	14	31 9	3·11	,,	74·0
Feb. 5	348,420	13	32 18	3·18	0·007	75·0
,, 12	277,480	10	22 1	2·60	0·006	83·0
,, 19	277,660	11	14 0	1·70	0·006	80·0
,, 26	301,264	14	18 3	2·10	0·005	86·0
Mar. 5	260,980	17	18 0	2·40	0·006	87·0
,, 12	270,900	23	24 10	3·14	0·006	75·0
,, 19	295,800	34	25 0	2·94	0·005	71·0
,, 26	301,550	37	27 4	3·24	0·007	77·0
Apr. 2	304,390	19	27 10	3·35	0·003	83·0
,, 9	289,368	22	20 4	2·51	0·003	84·0
,, 16	280,810	19	21 10	2·75	0·003	78·0
,, 23	276,080	9	17 0	2·20	0·003	72·0
,, 30	297,220	13	22 4	2·87	0·004	88·0
May 7	292,000	9	24 10	3·10	0·004	85·0
,, 14	283,960	9	26 4	3·31	0·003	92·0
,, 21	263,800	9	24 0	3·26	0·003	82·0
,, 28	280,462	5	27 7	3·50	0·003	83·0
June 4	285,580	6	30 0	3·77	0·002	83·0
,, 11	273,433	11	28 1	3·68	0·002	81·0
,, 18	284,807	7	28 18	3·65	0·003	93·0
,, 25	305,976	7	30 0	3·48	0·003	75·0

[1]After gas has passed through water-cooler and drier for use in gas engines.

Remarks—Inlet temp., 70 to 90 deg. C. Delivery temp., 70 to 95 deg. C. Preheater temp., 80 to 120 deg. C. Counterblast pressure from 4-in. water-gauge. Gas inlet pressure from 2-in. water-gauge. Gas delivery pressure from 5-in. water-gauge. Dust content of gas after passing through bag house only, 0.025 grm. per cu. m. Life of filter bags varies from 12 to 492 days; average, 285 days.

The bag house consists of 2 units, each of 20 compartments having 12 bags, that is, a total of 480 bags. Each of these 12-bag compartments in each unit is automatically shaken hourly to remove the dust, and during this time the current of gas is reversed in order to blow the dust from the pores of the bags. The gas on leaving the bag house contains on an average 0.025 grm. of dust per cu. m., and is used in this condition for stoves, boilers, etc. A portion of the gas which is required for gas engines is further cleaned in a water-spraying tower and dried in a tower packed with wooden grids. The dust content of the gas for the engines is about 0.004 grm. per cu. m. Particulars of weekly chart readings over long periods showing temperatures, power consumption, bag renewals, and dust content are given in the table. It will be seen that the bag renewals amount to 10 to 15 per week, and that the power consumed averages 0.075 to 0.085 unit per 1000 cu. ft. of gas cleaned.

On a three-month period when the plant was operating normally, the following figures per 1000 cu. ft. of gas cleaned were obtained:

Total wages	0.0287d.
Bags	0.0072d.
Stores and repair materials	0.0046d.

The all-in cost of running the plant, omitting depreciation and establishment charges, was 0.0778d. per 1000 cu. ft. of gas.

The capital cost of this plant at today's prices is approximately £23,000.

Plant X. Halberg-Beth Plant—This plant, designed to clean 4,750,000 cu. ft. of gas per hour, is composed of four separate units, each consisting of 10 double compartments containing 12 bags in each part, that is, 240 bags per unit, making a total of 960 bags. It is equipped with five Green economizers for controlling the gas temperature, to prevent either the burning of the bags or the deposition of moisture during filtration. Only one blast-furnace was operating at these works at the time that the gas-cleaning tests were made, so that only two units were in service. The hourly treatment of gas was estimated to be 1,800,000 cu. ft.

The whole of the gas cleaned is only required for burning under stoves and boilers, consequently there was no necessity to install the final spray washer and drier, as in the case of the last plant described. The comparison of the cleaning results must therefore be made on the dust content when the gas leaves the bag house. It was stated that one object of this plant when installed was the recovery of potash from flue-dust, but at present this is not being carried out. The dust content of the gas on entering the plant, as obtained over a series of tests for four or five weeks, details of which are given in the table, appears very variable, but is generally of the order of 5 grm. per cu. m., and

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†London, England.

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the cleaned gas on leaving contains from 0.1 to 0.2 grm. per cu. m., although some tests show a much higher figure. These results do not compare very favorably with the previous plant figures, but it must be borne in mind that this gas is only required for burning purposes. In the previous case some of the gas is used in gas engines, and the bag filtration must reduce the dust content as far as possible to enable the final spray to lower it sufficiently for that purpose. In this plant the life of the bags is considerably longer than in the previous one; under the conditions at this works it is more economical to get a longer life from the bags even at the expense of a somewhat less efficient cleaning of the gas. The power expended in this plant amounts to 0.11 unit per 1000 cu. ft. of gas cleaned, labor costs to 0.032d., and repairs, renewals, etc., including bags, to 0.0034d. The total cost of cleaning per 1000 cu. ft. is 0.0603d.

PLANT X—Halberg-Beth.

Date.	Dirty Gas.			Clean Gas.			Average Daily Temperatures.		
	Rate of Sampling. Cu. ft. per hr.	Volume of Gas Sampled (N.T.P.). Cu. ft.	Dust Content of Dirty Gas (N.T.P.). Grm. per cu. m.	Rate of Sampling. Cu. ft. per hr.	Volume of Gas Sampled (N.T.P.). Cu. ft.	Dust Content of Clean Gas (N.T.P.). Grm. per cu. m.	Crude Main. °C.	Cooled Main. °C.	Preheater Bottom. °C.
1927.									
July 28	...	...	...	5·2	12·1	0·353	230	94	93
„ 29	...	...	...	3·5	59·5	0·141	238	96	96
Aug. 3	...	...	...	3·3	17·7	0·220	268	97	95
„ 4	3·0	10·98	1·676	2·1	7·27	0·096	247	88	94
„ 5	2·6	10·07	8·510	...	...	...	247	93	95
„ 5	2·2	9·93	5·190	...	...	...	247	93	95
„ 6	2·6	11·88	8·730	...	...	...	238	93	94
„ 8	1·4	5·00	1·046	...	...	...	248	93	93
„ 12	...	...	...	3·9	84·3	0·024	224	87	96
„ 15	...	...	...	3·9	85·5	0·021	258	101	97
„ 16	...	...	...	3·2	17·4	0·347	273	99	97
„ 16	...	...	...	2·9	49·8	0·078	273	99	97
„ 17	...	...	...	2·8	12·0	0·368	260	91	92
„ 17	...	...	...	3·0	5·78	0·114	260	91	92
„ 18	...	...	...	3·9	17·05	0·178	259	92	93
„ 19	...	...	...	3·2	12·30	0·443	277	95	96
„ 22	...	...	...	3·0	9·32	0·156	274	92	95
„ 23	...	...	...	2·8	12·30	0·058	267	96	95
„ 24	...	...	...	3·2	13·50	0·131	266	91	94
„ 25	...	...	...	3·3	12·95	0·082	258	91	95
„ 26	...	...	...	3·2	11·36	0·128	242	89	92
„ 29	...	...	...	2·2	11·92	0·192	284	97	99
„ 30	...	...	...	3·6	16·58	0·217	287	92	96
„ 31	...	...	...	2·7	12·39	0·072	294	95	99
Sept. 1	...	...	...	3·5	16·48	0·117	279	91	94
„ 2	...	...	...	3·8	23·00	0·133	289	98	99
„ 3	...	...	...	3·2	10·98	0·145	286	95	97
„ 5	...	...	...	3·9	18·07	0·162	278	94	96
„ 6	...	...	...	5·3	26·65	0·128	280	98	93

Volumes corrected for an average temperature of gas as sampled of 20 deg. C. No record kept of temperature of gas leaving plant.

The higher dust content in clean gas as compared with Plant IX is due to gas being required only for stoves and boilers. Bag renewals are considerably less in this case.

Plant XI. Kling Weidlein Cleaner—This type of cleaner, which depends upon the gas being passed by its own pressure through chambers in which are fixed wire-wool mattresses, has been introduced into some works in England from America, but generally they have not been a success. Their object is only to give a gas suitable for burning in stoves and boilers; they are very cheap to operate as regards both power and labor, and undoubtedly serve to remove a considerable portion of the dust without losing the sensible heat of the gas.

This plant, which consists of five chambers, was one of the earliest erected outside of America, and was designed to clean 3,500,000 cu. ft. per hour. It is generally considered that the plant was rather too small to deal with that quantity of gas, and in the later designs more chambers have been added for plants of this capacity. The gas contained about 6 grm. of dust per cu. m. on entering the plant, and though numerous experiments were carried out, varying both the thickness of the mats and the coarseness of the wire-wool, it was not found possible to reduce the dust content regularly below 2 to 3 grm. per cu. m. Considerable mechanical difficulties were also met with, such as the breaking of the yokes during the periodical automatic shaking to clean the mattresses. By the time the mattress has become sufficiently clogged with dust to form a satisfactory filter, trouble is liable to arise on account of back pressure.

A series of tests carried out in 1923 is given in the table. The plant has not been in operation since the middle of 1925.

PLANT XI—Kling Weidlein. Five-Compartment Plant.

Date	Dust content of dirty gas Grm. per cu. m.	Dust Content in cleaned gas Grm. per cu. m.
January 6	5.48	2.79
January 12	5.50	2.59
January 19	6.34	4.05
January 25	6.21	3.32
January 26	8.20	2.98
January 27	6.76	3.18
January 29	9.88	6.00
January 30	7.31	3.60
February 4	4.79	1.58
Average of 9 tests over 1 month	6.85	3.34

Plant XII. Kling Weidlein Cleaner—This plant, consisting of a 10-compartment plant, is dealing with 3,200,000 cu. ft. per hour, each chamber being automatically cut off and shaken every two minutes. It appears to be the most successful one in England, and although the dust content in the clean gas is not as low as is desired, the upkeep and the cost of the cleaning are very low. The conditions of temperature under which this type of cleaner operates are most important. If the temperature of the gas becomes too high there is considerable destruction of the wire mattresses, and if on the other hand, it drops low enough to deposit moisture, the wet dust sets in the mattresses, and the chambers are put out of action. The gas temperature is therefore kept at about 150 to 200 deg. C. In this particular plant, the cleaner is so situated as to meet these conditions best, and consequently more satisfactory results have been obtained than at other works.

PLANT XII—Kling Weidlein. Ten-Compartment Plant.

Test No.	Temperature of gas entering cleaner deg. C.	Gas pressure In. water-gauge Entering cleaner	Gas pressure In. water-gauge Leaving cleaner	Dust content Grm. per cu. m. Dirty gas	Dust content Grm. per cu. m. Clean gas
1	110	3.75	2.0	9.67	1.87
2	143	3.0	2.25	5.15	1.43
3	143	3.0	2.0	8.83	1.87
4	197	2.5	1.5	9.56	2.78
5	160	2.25	1.5	3.39	0.77
6	149	2.25	1.5	5.26	1.25
7	193	3.0	2.0	11.90	2.23
8	190	3.0	2.0	5.22	1.56
9	177	3.0	2.0	5.40	1.44
10	190	6.0	5.0	6.76	2.00
11	188	3.5	2.5	6.93	1.53
			Average....	7.10	1.86

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The average dust content of the crude gas is 7 grm. per cu. m., and it is cleaned down to an average of 1.8 grm. Details of a series of dust determinations from this plant are given in the table. The power requirements are 0.003 unit, labor 0.004d., repairs 0.001d., wool and stores 0.0005d. per 1000 cu. ft. of gas cleaned; the total direct cost of cleaning is 0.019d. for this amount of gas.

The capital cost of this plant was given as about £20,000 at today's prices.

Two other plants of this type were visited, but it was found impossible to obtain results, as they had not been maintained in good working condition. In neither case could satisfactory results be obtained, even by using varying grades and thicknesses of the wire-wool, and at the present time the gas is being passed through to remove such dust as the mattresses are capable of retaining; no records are being kept, nor would it be fair to carry out tests on the apparatus as at present working.

From the results obtained from the four plants of this type, this cleaner hardly appears suitable for working under the conditions in England.

Possible Developments—There are two other types of apparatus which may be of interest, although no full-scale tests have yet been carried out on blast-furnace gas. The first is a new type of primary cleaner known as the Grant-Jones cleaner. It is in some respects similar to the Kling Weidlein apparatus, in that it is essentially a primary cleaner for supplying stoves and boilers, that the gas is filtered hot through a special material, and that the sensible heat of the gas is retained. In this apparatus the filtering medium is ground flint, which is evenly distributed over a traveling belt in two layers, coarse and fine; the belt of woven wire completely separates the upper half of the chamber, into which the crude gas is brought, from the lower half, so that all dust is drawn through the filtering bed. The flint with the dust is discharged by the endless traveling belt after its passage through the machine, and is then sieved free of the dust, regraded and automatically returned into the system. A small experimental plant was tried in the Midlands, and a larger plant is now being tried out at works in Leicestershire. A preliminary run has been made, but it is considered too early to do more than draw attention to what may develop into a valuable method of primary cleaning. The capital cost should be moderate, and there appears no reason to anticipate high operating costs.

The second type of cleaner has only been tried out on a blast-furnace plant in one small-scale experimental plant, where the conditions did not sufficiently resemble those required for satisfactory working for any reliable data to be obtained. It is of the cyclone type, which, as is well known, has been tried in very many different forms without any great success. This one has, however, been evolved after many years of experiment, and differs essentially from the ordinary types; it has given very satisfactory results in the removal of zinc dust in zinc smelting works, where a great number have been working efficiently for many years. The great attraction for a cleaner of this type is the extremely low capital cost of the plant, as it is believed by the inventor that satisfactory cleaning with this plant can be done with an outlay of hundreds of pounds instead of the thousands spent on the usual types of cleaners.

In Table I are tabulated the results obtained from the plants described above, from which it is possible to obtain a general comparison of the different types of plants from different aspects.

Comparison of the Results Obtained

In the following comparisons the results obtained at Plant I must not be included, as this plant is treating only a small volume of gas for engine purposes. Plant IX (Halberg-Beth) may, however, be fairly compared, as only a portion of the gas is being finally washed for engine purposes, and the additional cost of this washing is comparatively small.

In the author's opinion the results obtained by the Kling Weidlein plants show that this type of machine does not give even a reasonably clean gas for stoves and boilers, and that to obtain satisfactory results it must be worked in conjunction with a subsidiary cleaning plant. In the present comparisons of working costs, therefore, this type of cleaner is disregarded.

(*a*) *Comparative Cleaning Powers*—From the above tests it appears that the best results can be obtained by Halberg-Beth plants and by washing plants composed of spray tower and Theisen disintegrators, and that wet cleaners with spray towers only and the electrostatic cleaners are capable of cleaning down the gas to about 0.4 to 0.5 grm. per cu. m. The advantages obtained by burning gas cleaned to 0.4 or 0.5 grm. are very great compared with uncleaned gas, but there is a considerable difference of opinion whether this is sufficient to give the best results for water-tube boilers and similar purposes.

The exact point to which cleaning the gas for stove and boiler purposes can be economically carried (that is, to obtain the maximum heat development and minimum cost in refractories and repairs in relation to the cost of cleaning) is still an open question, but general considerations seem to indicate that a gas containing not more than 0.2 grm. per cu. m. gives sufficiently good results, and it is doubtful if further expenditure to decrease the dust below this is worth the extra cost.

(*b*) *Power Consumption*—In this respect the best results are obtained by the electrostatic plants, of which the "pipe treater" gives the lower figure. The latter plant is, however, working 50 per cent over capacity and yielding a rather less clean gas. If working to the capacity for which it is designed and assuming the same power were used, the figure would be 0.2 unit per 1000 cu. ft. of gas. The Brassert tower and spray cleaner is next in order, the Halberg-Beth plants and Zschocke fan plant come next, and the most costly in respect to power are the combined tower and Theisen disintegrator plants.

(*c*) *Labor Costs*—These are somewhat difficult to compare with any degree of accuracy, as they depend very considerably on the quantity of gas passing, as, provided no additional plant is put into operation for increased gas cleaning, the same labor can operate the plant for larger quantities of gas. For this reason the cost of labor in pence per hour, irrespective of the quantity of gas cleaned, is given in column 12 in Table I; for comparison purposes it seems that these figures and those in column 10 should be considered together. They show that the labor costs on the Halberg-Beth plant are highest, but that in the other cases there is probably very little difference in this respect. Plant V must be regarded as exceptional,

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TABLE I—Comparison of Blast-Furnace Gas Cleaners.

1. Plant No.	2. Type of Plant.	3. Approx. Capital Cost at to-day's Prices. £ per million cu. ft. capacity.	4. Capacity of Plant. Cu. ft. per hr.	5. Gas Cleaned per Hour at N.T.P. Cu. ft.	6. Average Dust in Crude Gas. Grm. per cu. m.	7. Average Dust Content in Clean Gas. Grm. per cu. m.	8. Electric Power. Units per 1000 cu. ft. Gas.	9. Water. Gals. per 1000 cu. ft. Gas.	10. Labour. Pence per 1000 cu. ft. Gas.	11. Repairs, Stores, and Renewals. Pence per 1000 cu. ft. Gas.	12. Direct Labour. Pence per Hr.	13. Operating Costs. Pence per 1000 cu. ft. Gas.[1]	14. Remarks.
I.	Spray tower, Jenkin fan, and Theisen washer	Not available	600,000	600,000	4 to 5	0·02	0·275	30	0·0406	0·0105	...	...	...
II.	Zschocke tower, Zschocke fan, or Theisen disintegrator	Do.	800,000	1,250,000	4 to 5	0·25 with Zschocke 0·02 with disintegrator	0·08 0·13	11½ 13½	0·0245	0·0040	30·62	0·0685 Zschocke fan 0·0935 Theisen	...
III.	Scrubbers and Theisen disintegrators	Do.	Over 5,000,000	Over 5,000,000	2 to 3	0·03 to 0·04	0·218	5·4 circulated 0·6 make up	0·006	Negligible at present	30·0	0·115	New plant. Dorr thickener and water recirculated
IV.	Brassert tower and Theisen disintegrator	7,000	2,500,000	Just over 2,000,000	6	0·15 to 0·20	0·15	55	0·024	Negligible at present	48·0	0·099	New plant
V.	Brassert tower, and sprayers	5,000	5,000,000	2,750,000	5 to 6	0·40 to 0·50	0·029	29 to 37 1½–2 make-up water	Nil. None extra employed	Negligible at present	Nil	0·013	New plant. Dorr thickener and water recirculated. Only working half plant
VI.	Lodge-Cottrell (pipe type)	15,000	2,000,000	3,000,000	5 to 6	0·40 to 0·60	0·013	...	0·0181	0·0023	54·3	0·0269	...
VII.	Lodge-Cottrell (plate type)	10,000	2,000,000	2,000,000	5	0·40	0·025	...	0·014	0·0025	28·0	0·0290	...
VIII.	Lodge-Cottrell (plate type)	9,000	6,000,000	3,250,000	4 to 6	0·30	0·0225	...	0·0063	Not available under present conditions	22·47	0·0180[2]	4 electrical machines working out of 6
IX.	Halberg-Beth	11,500	2,000,000	2,000,000	3 to 4	0·025 0·004 after final spray for engines	0·08	Very little; only portion of gas washed	0·0287	0·0118, including bags	56·4	0·0661	...
X.	Halberg-Beth	Not available	4,750,000	1,800,000	5	0·1 to 0·2	0·11	Nil	0·032	0·0034, including bags	59·6	0·0904	Only half plant working
XI.	Kling Weidlein	Do.	3,500,000	3,500,000	6	2 to 3	...	...	...	...	...	...	...
XII.	Kling Weidlein	6,000	3,500,000	3,200,000	7	2	0·003	...	0·004	0·0015	...	...	...

[1] Based on power at ½d. per unit.

[2] Labour, power, and stores only; no maintenance or renewals.

as the plant has been so arranged that all the labor involved is carried out by men employed on other work. Actually a portion of these men's wages should be allocated to the gas-cleaning plant, but no figures could be obtained on this basis.

(*d*) *Repairs, Stores, and Renewals*—This item will depend to a very considerable extent upon the length of time the plant has been in operation, and the figures obtained under this heading are not strictly comparable. Plants III, IV, and V have all been recently started up, and the wear and tear is consequently very slight. The most costly plant in this respect appears to be the Halberg-Beth, especially when being operated to reduce the dust to a minimum as in Plant IX. The difference between Plants IX and X is to a great extent due to the longer life of the bags in the latter, owing to the higher dust content permissible in the cleaned gas. There is not sufficient evidence regarding other plants to indicate any definite superiority in this respect.

(*e*) *Working Costs*—In order to obtain some comparison of the working cost of these plants, an arbitrary figure for power at ½d. per unit has been taken, and the total cost for power, labor, repairs, and renewals computed on this basis. In the majority of cases power is probably being obtained at a lower figure than ½d., but this has been chosen as a reasonable basis for comparison. The figures for the nine plants under discussion are given in column 13 of Table I.

In this comparison no charge has been made for the water used in washing, as in most cases this is obtained for the cost of pumping (included in power figure), and in others where water is not so available Dorr thickeners have been installed, which reduce the water make-up requirements to a very low figure.

From the above figures it appears that, on the whole, the electrostatic plant comes out most favorably. The Brassert tower and spray plant shows actually the lowest figure, but as already stated, no labor is allocated to the plant, and no maintenance has yet been necessary. These figures certainly would be very low under ordinary conditions, and such a plant would no doubt compare favorably with the electrostatic apparatus. The Halberg-Beth costs are clearly very much dependent on the state of cleanliness aimed at, as reflected by the bag renewals, but if worked to full efficiency the cost of operating seems to be about the same as those of the combined tower and disintegrator plants.

(*f*) *Capital Cost of Plants*—It has been extremely difficult to obtain figures for capital cost of plants, as in some cases where the plants have been of composite design different parts have been added at different times; in other cases plants have been installed when prices were inflated during the post-war period, and actual figures under those conditions would be only misleading. In column 3 of Table I are given the capital cost figures per 1,000,000 cu. ft. capacity for those plants for which it has been possible to calculate them at approximately present-day prices. Although the "capacity" of plants is a somewhat elastic figure, especially in the case of wet cleaning plants, this appears to be the most satisfactory basis to adopt for comparison. From these figures it appears that the plants for which the information has been obtained come in the following order, the most expensive being the electrostatic (pipe treater), followed by the Halberg-Beth, the elctrostatic (plate treater), and washing towers and disintegrators, the least expensive being washing towers with sprays, even when the cost of the Dorr clarifier is included.

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The First Iron Works in America—1645*

Based on Deposits of Bog Ore in Massachusetts and Obeying the Wish of the Early Settlers to be Self Supporting the First Works Producing Iron Was Established

By HOWARD CORNING†

THIS paper on the earliest iron works in this country, which really was of benefit to the colonies, is inspired by some 50 or 60 documents, the property of the Business Historical Society. The papers, original letters, inventories, and copies of agreements and testimony are not complete in themselves, but are probably all that is left of the file of some attorney connected with the suits in which the company later became involved. Information about the early years of the plant comes largely from the letters and papers of Governor John Winthrop and his son, John Winthrop, Jr. The records of the General Court of Massachusetts Bay Colony, the legislative body of the settlement, and of the Quarterly Courts of Essex and Suffolk counties have also yielded much supplementary information.

Massachusetts was not the first place in America where bog iron ore was discovered or even smelted. Two southern colonies both anticipated this venture; but the early discovery in North Carolina was not developed and the furnace put up in Virginia was destroyed shortly after it was constructed and was not rebuilt.

One of the necessities and desires of the colonists after crossing the Atlantic was to be as self-supporting as possible, and in this connection early search was made for iron. The early records of the colonists bound for New England show this. In March, 1628, over a year before the first large immigration to Massachusetts Bay, the governor and council voted: "also, for Mr. Malbon, it was propounded, he having skill in iron works and willing to put in £25 in stock it should be accepted as £50, and his charges to be born out and home for New England; and upon his return & report what may be done about iron works, consideration to be had of proceeding therein accordingly."

We have no record of any action which may have been taken on Mr. Malbon's report. The early years of the Colony were devoted to the necessary work of settlement and it is not until after 1640 that any active interest in iron is reported. Thomas Dexter and Capt. Robert Bridges found a deposit of bog iron in a part of what was then Lynn and is now called Saugus. Capt. Bridges is reported to have gone to England with specimens of the ore and he was no doubt ably seconded by John Winthrop, Jr. They succeeded in interesting 11 London capitalists to put in £1,000, and with this money Winthrop sailed for New England in the summer of 1643 with skilled workmen and material. We know of this through a petition he made to Parliament, dated probably 1643-4, in which he asked £1,000 damages for being held up by some official. As he said, he "did with costs and charges embarque himselfe with many workmen, servants and materials for the said setting up of iron works in said place." Six weeks time and a fair wind was lost and the An Cleve in which they sailed did not reach Massachusetts Bay until too late in the fall for any work to be done, so that the workmen had to be kept in idleness all winter.

Location of the Works

The site chosen for the works was on a stream near a water power not far from the ford on the highway to Boston. To this day near the present highway is a large cinder bank, the result of the operation of these works, and across the road stands one of the houses used by the company. The site was for a long time referred to as Hammersmith after the place in England from which the skilled workers came.

The records of the general court show the negotiations for what was the equivalent of a charter. The "undertakers for the iron works in New England," as they were called, were given a monopoly for 21 years to erect works in six different places, which, however, must include forges as well as smelters. In any place selected they were to have three miles square "Which is 12 miles in compas" of land then unappropriated—all this, provided the works were erected within three years. There was some argument about this last condition, but the court shrewdly refused to lengthen the time in which to build. Certain remissions of taxes and all freedom from "trainings and watchings" were granted to the company and its servants. It was also stipulated that the iron should be sold at not above £20 per ton.

The subsequent history of these iron works is an interesting human story which, if taken out of the conditions and manners of the seventeenth century, would seem quite up to date. John Winthrop, Jr., had been instrumental, as stated, in starting the enterprise. He was educated at Trinity College, Dublin; had traveled in Europe as far as Constantinople, and, as his letters show, had a lively interest in what then passed for the sciences. We later find him opening a black lead mine near Southbridge, Mass., and he was active in other enterprises. Evidently he hoped to be agent for the new iron works, but Richard Leader was appointed instead. Emanuel Downing, Winthrop's uncle, wrote him from London on the twenty-fifth of February, 1644.

> The adventurers in the Iron works have agreed with Mr. Leader to take care of theire works. You know the man. He lived in Ireland. He is a perfect Accountant, hath skill in engines and tryall of metalls, he hath covenanted to serve them 7 years, his wages is £100 per annum. He is to have passadge for himself, his wife, 2 children, 3 servants; an howse to be built for him and ground to be allowed him for his horses and a few cowes. His £100 per annum begins the 25th of Marche next. When I perceived they were resolved upon him: and that it would be noe advantage to you for me to have exposed my dislike to theire way herin, but have put more Jealousies into their heads of you: and when they asked

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†Business Historical Society, Harvard University, Cambridge, Mass.

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me what I thought thereof, I answered that you had travayled from East to West, from North to South, sparing noe costs or paynes for the discoverie of mynes and fitt places for erecting of Iron works and how you obteyned 3000 acres of Boston, 1500 of Dorchester, wherein you have deserved well from them, and, that there will be great neede of your helpe though they send one never soe sufficient for the work, whereto they replyed that they resolved to satisfie you for the tyme past, and to desire your assistance for tyme to come.

And so the works were completed and commenced to smelt ore, and like many another enterprise spent more money than they planned. To their rescue came the general court with the following:

Whereas it is now found by sufficient proofe that ye iron worke is very successful (both in ye richnes of ye ore and ye goodness of ye iron) and like to be of great benefit to ye whole country, especially if ye inhabitants here should be interested therein, in some good proportion, (one halfe at the least), and whereas ye time limited for adventurers to come wilbe expired in the 9th Mo. next, this Court taking ye same into a serious consideration, and being careful that such an opportunity for so great advantage to ye commonwealth might not be let slip, have taken order that speedy notice thereof should be given to every towne within this iurisdiction, expecting that all persons as are of sufficient ability and intend their owne benefit, with ye comon good, will forthwith appeare, to come in to share in ye worke, according to their abilities: and for their better instruction and direction herein they are hereby to understand that there is already disbursed between £1200 and £1500 with which ye furnace is built, with that which belongeth to it, and good quantity of mine, coale and wood provided & some tuns of sowe iron cast and some other things in readiness for ye forge etc. They are also to know that no adventurer is to put in lesse than £100 but divers may ioyne together to make up that sume, so it come under one name: there wilbe neede of some £1500 to finish ye forge etc., which wilbe accepted in mony, beaver, wheate, coales, or any such comodities as will satisfy ye workman, and these are to be paid in to Mr. Henry Webbe, of Boston, by such direction as they may receive from ye undertakers, Mr. John Winthrop, Iuni., Maior Sedgwick, Mr. Henry Webb aforesaid and Mr. Joshua Hewes. The new adventurers are also to know that they must beare their part in such losse as is befallen ye first stock, by forbearance, or otherwise, to ye time of ye newe adventurers paying in their adventures; & all such as will adventure are desired to hasten their resolutions, that ye worke may go on spedily.

We hear a great deal nowadays of customer ownership and the great advantage accruing to all concerned, together with the intimation that it is a clever modern idea. It seems as though the general court over 280 years ago had covered the whole matter when they urge all persons who "intend their own benefit with the common good" to subscribe to this private undertaking.

How much was subscribed we have no means of knowing, but the works were finished. That they were successful, from the colonists' standpoint, seems certain. Governor Winthrop wrote on two occasions:

"The iron work goeth on with more hope. It yields near about 7 tons per week, but it is out of that brown earth which lies under the bog mine. They tried another mine and after 24 hours they had a sowe of about 500 which when they brake, they conceived to be a 5th part silver. There is a grave man of good fashion come now over to see how things stand here. He is one who hath been exercised in iron works." And again in the same year, "The furnace runs 8 tuns per week and their bar iron is as good as Spanish."

But in London things did not look so bright. The merchants there had invested their money, and as their correspondence showed, honored drafts and now wanted some return. The new world then was supposed to be rich in gold, silver, and baser metals which might almost be had for the asking, and letters of complaint were written. The following answer is taken from the records of the general court: it shows that those in power here needed no guide to tell them how to soothe the irritated. At the same time it hints that they could do as well elsewhere.

A reply to a letter from the undertakers of May, 1646, reads: "We perceave your discontent with ye last agreement wee made with your agent Mr. Leader." This probably refers to the conditions made in granting a petition recorded at a court held November 4, 1646. Also the letter must have asked for a shipment of money based on the sales of iron to the colonists, for the letter also stated:

Wee acknowledge with you that such a staple comodity as iron is a great means to inrich ye place where it is, both by furnishing this place with that comodity at reasonable rates and bringing in other necessary comodityes in exchange of iron exported; but as wee vse to say, if a man lives where an oxe is worth but 12d, yett it is never the cheaper to him who cannot gett 12d to buy one, so if your iron may not be had heere with out ready money, what advantage will that be to us, if we have no money to purchase it? It is true, some men have here Spanish money sometimes, but little comes to our smiths hands, especially those of inland townes; & yourselves well know, that so long as our ingate exceeds our outgate, ye balance must needs be made by much with in such portion as it is with vs....but if wee must want iron so often as our mony failes, you may easily judge if it were not better for us to procure it from other places (by our corne & pipestaves etc.) then to depend on ye coming in of mony which is neur so plentiful as to suply for ye occasion....

In a petition it was asked that the time limit already increased to 10 years for setting up the works be extended to 21 or the limit of the grant. This was refused and this explanation given, "If those 6 workes should take up all our fit places, & when your terme is expired, some of ours should have meanes to erect any such worke, wee should have ye bennefitt thereof etc." The reservations were shrewdly made and a little later we find the court taking advantage of them. This was in 1657 when there was a temporary shut down and the company owed much money in the Colony. The general court then granted parties in Concord and Lancaster the right to erect iron works in that neighborhood, stating that the present works were not likely long to continue, that they had not supplied the colonists with iron as needed because they did not have it on hand, and that they had charged above £20 per ton. They were still just to the old company, however, in that they gave them the right to buy out the new works within the year and prohibited any solicitation of workers from Lynn.

The truth of the matter was that the works were supplying castings, wrought iron, and steel to the colonists in small lots as needed, pay being taken in the only media available, namely, beaver, wheat, and anything else of local use, including wampum. Little of this except beaver could be shipped to England, and with the fluctuations in value it is doubtful if the works had much profit from which to pay a return. The next step of course was to send over an overseer and Governor Winthrop states it as follows: "The adventurers in England sent over one Mr. Dawes to oversee Mr. Leader etc. but he is far short of Mr. Leader. They could not agree, so he is returned by Teneriffe," and Leader about the same time wrote to John Winthrop, Jr.: "The company is very much discontented and use me not as I deserved. They have sent one over to take account of things and to give them

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satisfaction how things stand with us. But I am in some doubt they will be failed of their expectation in him."

Before we take up the stormy career of John Gifford, the next agent, it may be as well to tell something of the raw materials and the product. I have already mentioned the "Bog myne," as it is called in the accounts. Just where it was dug up is not certain except on the land of Adam Hawkes whose descendants still live on part of it. This was supplemented by an iron ore from Nahant. The location of this is even more uncertain, but we know it was a ledge, for it was obtained by building a hot fire on the ore and then pouring water on the heated rock. Local tradition attributes their lime to shell heaps of which there are remains in the neighborhood, and at many other places along the coast. There is also a record of two tons of limestone imported from England—this material not being discovered in the colony until 1697. The charcoal came from the trees on the 3,000-acre grant and much reference is made to cutting wood and hauling "coales" which must have kept a large force busy.

Governor Winthrop referred to their bar-iron being as good as Spanish. The works as already suggested produced cast and wrought iron, and perhaps some steel. The first pot cast is now in the public library at Lynn, having been handed down in the family to whom it was given in part payment for some land bought by the company. In addition to a furnace and a forge a "slittin" mill was set up for cutting bar iron into rods out of which nails were forged. A small plant was also erected at Braintree. An inventory made about 1654 shows one lot of 36 anchors weighing about 60 lbs. apiece—cast pans in addition to pots, forgings of all kinds, tools, such as "4 croscutt sawes not fitted," and nails and spikes. The product went into all the surrounding country. There is record of a shipment to Piscataqua, now Portsmouth, where the first agent, Richard Leader, established himself. Again there is a record of a ship sent with pots and other goods on a trading voyage to the "Dutch and Delaware" in 1651-2, and one also to the Barbadoes. We have the testimony of William Osburne that in the latter part of 1652, or early in 1653, a ship load of iron was sent to John Becx in London.

One of the earliest papers in the society's collection is the agreement made by the 11 men in London with John Gifford. This agreement was dated "in ye yeare of our Lord god according to the Computation of ye Church of England one thousand six hundred and fifty." In August of the same year a letter was sent to Mr. Webb and Mr. Tynge who were in this country and had been appointed a committee to represent the undertakers, informing them of Mr. Gifford's appointment.

Mr. Webb & Mr. Tynge

Graucsende this 28 August 1650.

It is the Companys desire to Certefye you that Mr. Leader hath dismist ye works by ye Consent of ye Company and is mynded to follow his other occations, and that they haue sent over Mr. Gifford to succeede in his place for to manadge ye Works at Lyn & Brantre, and likewise Mr. William Awbrey to Liue in Boston to keepe our accompts, and to bee as a factor to Negotiate for any thinge that concernes ye Company whereby they may haue all things made plain & cleere constantly to their view, and that all ye goods & fishings Craft that are in your hands or in any of ye Company be deliuered into the ware howse which Mr. Awbrey shall keepe for ye Company's Use. Wee woold desire you to certefie theise things to the rest with you that are conserned, and further that you woold afforde your best assistance to them in all necessary businesses wherein the good of the Company is conserned, that so through gods blessingge upon all good endeauors booth with you & vs the business may succeede to all our contents, not haueinge further at present wee take our Leaue resting.

Yor Loueinge freinds

John Becx
William Hiccoke
Joshua Foote.

William Awbery was the company bookkeeper and a statement signed by him in December, 1651, gives some idea of the business for that year.

Rec this 25th December 1651 from Mr. John Gifford An Abstract of his Bookes from December 1650 to December 1651 in which It doeth appeare that I haue Creditt from Mr Gifford by he seuerall perticulers therein specifyed for the some of Two Thowsand one hundred and fowrty pownds seauentyen shillings & Six pence in moneys, & bills and am Charged with Sixty Fiue tonn seuen hundred and 23lbs of Barr Iron Twelue Tonne one hundred Two quarters of Rod iron—seauen ton fowr hundred one quarter & 25lbs of potts & cast ware Beeinge the substance of accompts to this day beeinge the 24th day of December 1651 Excepting prouitions which wee can not yet account till wee haue examined and Cleered with the shops Boston this 24th December 1651.

William Awbrey.

The latter years of the company itself were full of suits and countersuits which it would be pointless and tedious to follow. The society hopes at a later date to give a fuller account of this and other iron works in the colonies. It is the old story of an absentee ownership complicated with new conditions and very uncertain communication. Even at this early date there are complaints of the high cost of wages and the high cost of living, and it could not be understood why it should cost five shillings a week to "dyett" a man "you haveing ther plenty of fish, both fresh and salt and pidgions and venison and corne and pease," and the agent was told to have them boarded at 3s. 6d.

In addition the mistake was made of dividing the authority between Gifford and Awbery. Gifford was supposed to render weekly accounts of progress at the works which he was no doubt too busy to do. The plant was run down and had to be put in shape again, but, as money was not forthcoming, bills began to accumulate. There are two copies of drafts returned from London dishonored with the accompanying expense and a long letter to Gifford full of instructions and complaints.

Finally on the twenty-eight of June, 1653, the matter was taken to the courts and Capt. Robert Bridges, Mr. Henry Webb and Mr. Joshua Foote were appointed commissioners and attorneys for the company to recover the £10,000 disbursed by the agent. The upshot of it was that the creditors took possession. Mr. Henry Webb wrote two letters to the owners in London showing what a rascal Gifford was, but in the end he confessed that he was also a party to the suit of the creditors. The larger claims were assigned to Capt. Thomas Savage making a total of £3,618 15s. 4d. and of this Webb's claim was £1,351 6s. 9d. It is not surprising that a new committee was appointed in spite of the explanatory letters.

Capt. Robert Keyne and Mr. Joshua Winslow appear as attorneys for the company in 1654 and Gifford was imprisoned. He sued these two men for false

(Continued on page 1090)

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Sheet Steel for Automobile Bodies

The Process of Annealing Is Reviewed Together with Its Importance and Control—Equipment and Methods of Annealing in Single Box Furnaces Described

"AUTOSHEET"

PART VI

ANNEALING is one, if not the most important of all processes in the manufacture of automobile body sheets and both literally and figuratively is "the making or breaking" of drawing quality sheets. For this reason too much emphasis cannot be laid to this particular part of the mill processing on which volumes have been written and there remains a great deal more to be learned.

The term "anneal" is confusing as it is very likely that in different plants the term is used to mean widely different things. Thus to many the term "annealing" means that operation by which the steel is heated above the critical temperature range and then is allowed to cool very slowly while others conceive of it as merely an operation of heating and cooling, resulting in a softening of the material. If then, we are to define annealing we must first decide whether such a definition refers primarily to the heat treating process or the results obtained by such a heat treatment. In other words does this definition point toward the final microscopical structure obtained or of the operation performed on it? A collaboration of ideas from such societies as the Society of Automotive Engineers, American Society of Testing Materials and the American Society of Steel Treaters points to a joint agreement that "annealing should refer to the heat treating operation itself and not to the resulting structures." Such an opinion seems logical enough and for a general statement seems to cover the definition for annealing, but for one who is primarily interested in obtaining such physical properties that will make a sheet suitable for the most difficult auto body stamping, modifications of this definition are in order.

Annealing usually implies a slow cooling and while it is usually the practice to slowly cool sheet steels for maximum ductility and softness, the slow cooling aggravates a combination of the grains of iron or so called "grain growth" which is undesirable. While we want maximum softness and ductility it seems advisable to sacrifice a little of these properties by a heat that is sufficiently high to relieve the internal strains set up by the rolling on the hot mills. Of the two evils grain growth and internal strains, grain growth is the lesser and it is the opinion of the writer that the prime essential of annealing sheet steel is to first remove these internal strains before any further refinement of structure and physical properties is attempted. Microstructural examination of hundreds of so called extra deep drawing sheets shows that they have been annealed with but one thing in view, namely—a maximum softness and ductility. This viewpoint has often resulted in improper heat treatment and in a majority of cases all of the internal strains have not been relieved. Excellent examples of such conditions will soon be illustrated.

Before getting deeper into this subject, let us outline in the order of their importance the reasons for annealing from which we should derive a definition for anneal which may be applicable to sheet steels. Annealing is therefore made:

1—To remove internal strains set up by the rolling in the hot mill and cold rolls which subsequently causes a distortion of the crystalline structure.

2—To refine coarse or large grain structure, thereby increasing its ductility, strength and elasticity. This refinement of structure gives the sheet a decided advantage under the action of stamping or drawing it to shape.

3—To soften the steel in order for it to possess such drawing properties that it will be suitable for the automobile part intended.

4—To remove gases occluded near the surface of the sheet and to slightly alter the physical properties such as tensile strength, elastic limit, hardness and ductility.

Methods of Annealing

The above reasons for annealing resolve themselves into two methods for the maximum refinement of sheet steel. These two methods which may be followed are called "full" or true annealing and "works" or process annealing. The main difference in these two processes lies in the fact that the "true" anneal carries the sheet temperature above its upper critical range (1,616 deg. F. for a 0.10 per cent carbon steel) while the "works" anneal carries the sheets to a temperature well under the critical range. These two methods of annealing, together with the above reasons for anneal, are best summarized as follows:

The "full" or true annealing of low carbon sheet steel is an operation or combination of operations whereby the steel, in a solid state, is heated above its upper critical range, held there sufficiently long to relieve all internal strains and refine, so far as the treatment will permit, its crystalline structure by a relatively slow cooling to atmospheric temperature.

The "works" or process annealing of low carbon sheet steel is an operation or a combination of operations whereby the steel, in a solid state, is heated to a point somewhere between its upper and lower critical ranges, held sufficiently long to relieve any internal strains or occluded gases and refine, so far as the treatment will permit, its crystalline structure by a relatively slow cooling to atmospheric temperature.

The operation or combination of operations needed to accomplish these results consist of first heating the steel to a certain predetermined temperature and then keeping this temperature constant for a definite length of time which is called the soaking period and finally allowing the steel to slowly cool to atmospheric temperature. This cycle of heating, soaking and cooling

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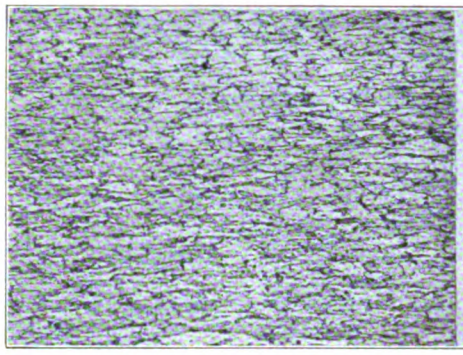

FIG. 1—Longitudinal section of "black sheet" from hot mill. Note distorted and elongated grains.

FIG. 1A—Longitudinal section of .10 carbon sheet heated to the critical range and slowly cooled. Black spots from excessive etching. Note traces of strain still remaining.

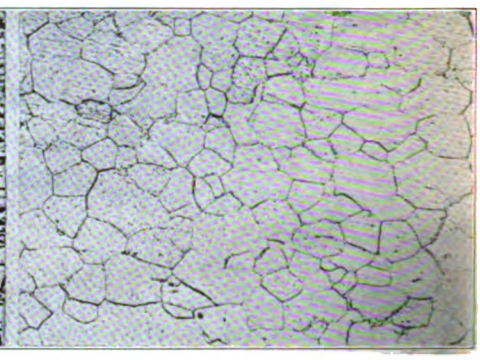

FIG. 2—Longitudinal section of equi-axed structure. Note pearlite (dark) between grains of ferrite (light).

X100, etch HNO_3, top edge parallel to direction of rolling.

is followed in any thermal refinement of sheet steel after it leaves the hot mill in the form of black sheets.

If the sheet is to receive only one anneal in its processing it is probable, in most cases, that the anneal is carried above the upper critical range for the maximum grain refinement, relieved strains and improved ductility possible in that one anneal. In that event we should use the true annealing temperature which will range from 875 deg. C. (1,608 deg. F.) to 920 deg. C. (1,690 deg. F.) with the fixed temperature somewhere between these two limits depending on the equipment used and the conditions of heating. True annealing is also carried out at slightly higher temperatures than those mentioned above under a new and more rapid process called "normalizing" which will be discussed later. In bringing the steel above its critical point the true anneal changes the aggregate of pearlite and ferrite to a homogeneous solid solution called "austenite" and if it is held long enough in this state, the strains set up in the mechanical handling of the steel are obliterated. It is of interest to point out at this time that unless the heating to the predetermined temperature is constantly and fairly slowly raised and then held within close limits at this temperature the results desired are not always attained. This will presently necessitate a discussion of the equipment, fuels used and method of handling. If this true anneal is the first of two or more anneals in the manufacture of a full finished automobile sheet it is commonly termed "black annealing." This can be attributed to the fact that this is the anneal which "black sheets" from the hot mill usually receive.

Between the black annealing and the final anneal, if any, we may have pickling or cold rolling or a combination of these two factors. The cold rolling has distorted the grains of ferrite and pearlite near the surface and the pickling has introduced absorbed hydrogen gas, thus making it necessary for another annealing to restore the ductility by relieving the slight strained condition of the ferrite and pearlite and to remove this hydrogen gas.

Both of these factors while small in amount are sufficient to somewhat decrease the ductility and slightly embrittle the steel. We therefore anneal the steel at some predetermined point below its critical range which we have previously termed the "process" anneal. This temperature will range from about 600 deg. C. (1,115 deg. F.) to 850 deg. C. (1,562 deg. F.). Unless the pearlite present has been distorted, the soaking period need not necessarily be as long as that same period for the true anneal. In the case of sheet steel this is true due to the fact that in a 0.10 per cent carbon steel there is theoretically only 12 per cent pearlite present. It is quite obvious that the small amount of this pearlite that is near the surface and which may have been distorted by a pass or two in the cold rolls, will be practically negligible in its effect on the resulting physical properties. This process anneal is usually called "white annealing" as it is carried out on sheets which have previously been "black" annealed and then pickled.

Annealing and Crystallization

We have discussed to some length, in a previous issue of this magazine, the cause and formation of crystallization, the effect of hot and cold working and the cause of grain growth. While such a discussion could be profitably repeated here it would be well to restate briefly only those factors in which we are interested at this particular point. Let us first consider the black sheet, badly strained from excessive rolling below the lower critical range (Ar_1) as illustrated in Fig. 1. We are going to reheat this steel in view of relieving the stresses and to soften it as much as possible.

In spite of the excessive amount of rolling the steel has more or less followed its normal conditions of cooling so far as the distribution of its constituents are concerned. Critical examination of this 0.10 per cent carbon steel will show that it contains approximately 12 per cent pearlite (cementite plus ferrite) and 88 per cent free or excess ferrite in the alpha state, the pearlite being in small distorted grains completely surrounded by a network of distorted ferrite crystals. Now if we anneal such a steel we find that as it passes up through the lower critical range Ac_1 (approximately 1,300 deg. F.) the pearlite changes to austentite wherein the ferrite used to make up this pearlitic state has changed from the alpha to gamma form. However the excessive ferrite present is still in the alpha form. All constituents at this point are still badly strained. (Note Fig. 1A.)

Continued heating causes the austenite to begin absorbing the excess ferrite in the gamma form and gradually all of the ferrite is thus allotropically changed and absorbed until we reach the Ac_3 or upper

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critical range (approximately 1,560 deg. F.), At this point all of the ferrite has been changed and taken into the austenite as gamma iron. The strains at this point are supposed to be obliterated but we are led to believe that while the major portion of the strains have been relieved the length of time that this steel is held on or above this temperature (soaking period)

FIG. 3—Furnaces and boxes for annealing sheet steel.

has considerable to do with the complete elimination of strains which is most essential. This conclusion is based on the fact that a badly strained sheet steel annealed just to the upper critical range and then slowly cooled still shows the presence of a small amount of "directional stress" in spite of fairly good crystalline refinement. This is also confirmed by transverse and longitudinal tensile strength tests. (Note bottom test in Table I, as well as microphotograph—Fig. 1A.)

Under normal conditions such as reheating a cast metal wherein the steel, to begin with had more or less of a definite crystallization, we would find a maximum refinement of grains at the Ac_1 point. However, the strained condition of sheet steel prevents such a refinement at this point and necessitates their complete removal and a recrystallization of the steel simply because an excessive amount of rolling has been necessary to get sheets to such thin sections.

We therefore have the steel heated to a point above its upper critical range with its constituents present as a solid solution of austenite. Assuming that the temperature has been held to within a fairly close range and that this soak has eliminated all internal strains we must now cool to room temperature. For sheet steels this cooling is very slow and the sheets are excluded from air by being packed in air tight cast iron boxes. This slow cooling is necessary for (1) maximum softness and ductility, (2) uniformity of grain size and structure, (3) preventing the presence of air which would oxidize the sheet and (4) formation of normal pearlite. It is not necessary to again discuss the first two reasons for slow cooling. The third reason, that of the presence of air, is best illustrated under annealing equipment but the fourth reason demands a slight explanation. It must be well understood by now that we are seeking in annealing sheet steel the maximum ductility that is possible after the surface has been added. We also understand that free ferrite is the softest constituent with pearlite the next hardest constituent present. It is for this reason that we keep the pearlite quite low in sheet steel. For commercial sheet steel we cannot very well avoid the presence of pearlite and neither do we wish to exclude it entirely, as it strengthens the sheet which is an important factor. However we do want the pearlite that is present to be segregated which is best brought about by a slow cooling of the sheets. Slow cooling promotes the presence of coarse austenite and allows the maximum amount of free iron to be rejected from it leaving only enough iron to combine with the cementite (Fe_3C) to form pearlite when the Ar_1 point is reached. This rejection of all the excess ferrite is what we desire since these grains of ferrite are the "backbone" of the sheets' softness.

If the cooling is exceedingly slow, each grain of coarse austenite rejects from it the excess ferrite which completely surrounds it as a network. This coarse austenite then changes bodily to a coarse crystal of pearlite at the Ar_1 point and as just stated is completely surrounded by a network of ferrite. This is best illustrated in Fig. 2 and is typical of a good drawing sheet steel. (The pearlite is represented by the dark areas and the ferrite by the light areas.)

Now if the rate of cooling had been increased the austenite would still be in a semi-segregated condition and as a result would be holding some ferrite which should have been precipitated from it. Pearlite in this phase is called "sorbite" which is nothing more than a transition point of the austenite to pearlite. "Sorbitic pearlite" is what we would have on a fairly rapid cool of sheet steel which deprives us of some ferrite which we should have for maximum softness and ductility.

TABLE I—Relative Tests from Box of Full Annealed Sheet Steel.

		Top of pile	Middle of pile	Bottom of pile
Position of test sample		Top of pile	Middle of pile	Bottom of pile
Micrograph X100		Fig. 7 (A and B)	Fig. 8 (A and B)	Fig. 9 (A and B)
Condtion of structure with regard to the anneal temperature		Coarse grained	Slight grained	Slight grained slight internal strains
Ductility in MM (Erickson)		10.4	11.0	9.7
Ducitlity in inches (Olsen)		.386	.389	.376
Hardness (Brinell 500 lb.)		65	70	74
Hardness (Rockwell 1/16-in. ball, 100 kg. weight)		28.5	30.0	34.0
Longitudinal section of sheet	Tensile strength	37,200	36,950	39,480
	Elastic limit	23,240	22,460	28,200
	Elongation in 2 in., per cent	40.6	43.2	39.2
	Elongation in 8 in., per cent	33.2	34.3	29.7
	Reduction in area, per cent	45.9	40.3	38.1
	Surface at fracture	Grainy	Grainy	Grainy
Transverse section of sheet	Tensile strength	42,150	41,300	43,710
	Elastic limit	25,010	24,420	27,500
	Elongation in 2 in., per cent	39.8	39.6	38.7
	Elongation in 8 in., per cent	32.8	33.9	30.1
	Reduction in area, per cent	35.4	35.3	33.8
	Surface at fracture	Grainy	Grainy	Grainy

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Therefore, a slow cooling not only causes large pearlite grains but this maximum rejection of ferrite causes coarseness of structure by its crystallization into large grains. This is the disagreeable feature of slow cooling but its disadvantages are compensated by its advantages. Careful annealing temperature control will help to regulate such growth with only a slight loss to its physical properties. In this respect too long a soaking period will, along with its slow cooling, cause grain growth.

Annealing Equipment

The fact that we are discussing only full finished automobile sheets whose physical properties must allow drawing it into the most difficult shapes demanded of sheet steel, makes it necessary to use annealing equipment not only to obtain these properties but it must also protect the surface in so far as possible. For this reason we are not interested in, nor will we discuss the question of "open annealing" which, as the definition implies, is the heating and cooling of sheet steel without protection from the air.

The elimination of open annealing will next bring to our attention "box" or close annealing as it is sometimes called. Box annealing is the standardized method of treating sheet steel and implies that the annealing is protected from the presence of air by this box equipment. Box annealing equipment, in turn consists of an annealing furnace, a cast iron tray and cover and suitable apparatus for the charging and pulling of the box in and out of the furnace. The furnaces are usually built to hold one, two or four annealing boxes and are designated as single, double and multiple box furnaces respectively. For the most part single and double box anneal furnaces are in favor due to various factors affecting an uneven heat distribution for a furnace containing more than two boxes.

The furnaces are simple in design, being about 16 to 18 ft. long, 8 to 9 ft. wide and of about the same height. One end is closed while the other end has either sliding or swinging doors which open and close to permit the entrance and exit of the box. The sides and back end of the furnace are lined with fire-brick with the roof arched and made of the same material. This brick inclosed furnace is reinforced on the outside by structural shapes and staybolts. The heat medium for the furnaces is usually natural, producer, coke oven or coal gas. If natural, producer or coke oven gas are used it is usually admitted through flues and muffles extending along one or both sides and near the bottom of the furnace. If coal gas is used, the firebox is under the furnace with the resulting heat and gas coming up through flues and out over a muffle wall which is about 2 or 3 ft. up from the floor and usually only on one side of the furnace. Thus in a coal fired single furnace the gas comes up through and over the muffle wall and hits the arched roof causing the gas to circulate over the top of the box. The exit flues are beneath the box which insure as good a distribution of the heat as can be expected from this type of furnace. Double box annealing furnaces, if they are coal fired, have the gases coming up through a muffle wall which stands between the two boxes, the gas dividing itself and circulating in a similar manner to that of a single box furnace. The circulation of gas in both the single or double box furnaces is best illustrated in Fig. 4. In all types of furnaces, whether one, two or multiple box, the products of combustion are carried away to the stack through the flues under the boxes.

The box is made up of two parts; the bottom or tray and the top or cover, both of which are cast iron. These are shown in Fig. 3 and are of such a size that they will accommodate the largest sheets that will be annealed. The outside of the cover on all sides and top is reinforced with heavy ribs running at such angles to each other that they help to prevent warping and buckling of the box under a fairly high heat. This

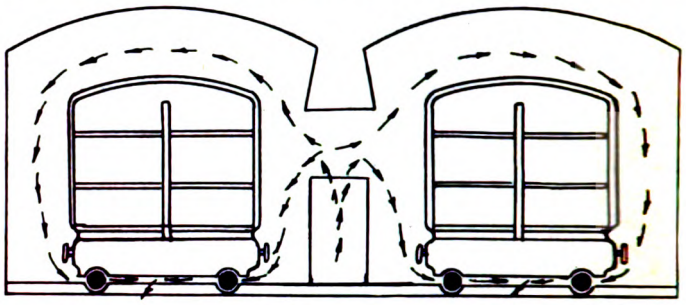

FIG. 4—Circulation of gas in a double box annealing furnace.

lengthens the life of the cover remarkably due to the fact that it is rapidly heated and cooled as it is charged and drawn respectively. Contrasted with this reinforced outside the inside of the cover is smooth and free from any protruding sides which might catch on the sheets as the cover is lowered over them. The cover carries four lugs, two on each side near the ends and well above the center line of the box, onto which crane hooks can be fastened thus facilitating easy handling. The bottom or tray is a cast plate whose upper side is flat and having a rim running around the edge about 6 in. in height. The dimensions inside of this rim are perhaps 8 or 10 in. longer and 6 or 8 in. wider than the outside dimensions of the cover thus allowing its easy fit. The under side of this bottom has two or three semi-circular grooves which run parallel to each other the entire length of the bottom. These grooves serve as ball races and hold in place iron balls which in turn rest on steel guides which run into the furnace. The bottom also carries four lugs placed two on each side and near the ends and serve to lift the tray by crane.

Loading and Charging

The steel to be annealed is first placed on the tray with sheet bar placed between either the various sizes or in such sections where we might wish to place thermocouples for recording the temperature of that part of the box during its anneal. Assuming that we are desirous of obtaining the temperatures near the top and bottom let us place two thermocouples as indicated in Fig. 5. If the piles of steel vary in size we will place the largest sizes on the bottom and gradually reduce the widths until the top pile is the narrowest in the box. The lengths of the various piles must also be considered with the longest sheets on the bottom, gradually tapering in length toward the top; otherwise the excessive length, extending out over the pile beneath it, will sag under the heat of the anneal and cause its probable rejection when inspected. However, we will consider the box containing but one size as indicated in the sketch.

The size of the pile will vary from 25 to 40 in. in height and weighing anywhere from 20,000 to 50,000

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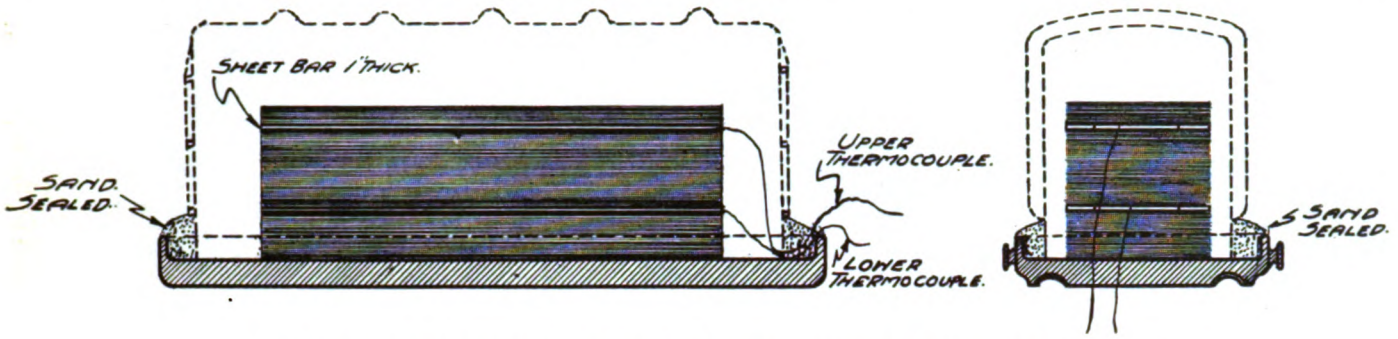

FIG. 5—Relative positions of upper and lower thermocouples in box of sheet steel. (End of couples about the center of pile.)

lbs., depending, of course, on the size of the sheet. After the sheets have been piled and the thermocouples inserted where desired, the lead wires are laid along the bottom and over the end of the tray nearest the door of the furnace. An overhead crane then hooks onto the four lugs of the cover and drops it over the pile. The space between the wall of the cover and the rim of the tray is next filled with fine sand, called the "sand seal" which must keep the air from entering the box, in so far as possible during its heating and cooling. The loaded box,, now ready for the furnace, is picked up by the four lugs on the sides of the tray and slowly lowered onto the track. The box then rests on the cast iron balls with the grooves on the under side of the tray in line with the grooves of the track. By means of an electric pusher or a suitable mechanical contrivance the box is pushed or pulled into the furnace, doors closed and the annealing is begun.

Based on the definite mass of steel that must be annealed to a predetermined temperature we should calculate the length of time that the steel should heat and soak in order that it will be thoroughly annealed. The type of furnace, fuel used, and method of firing are all factors that enter into the equation. In this example of annealing we will use coal, the gas entering the box over a bridge wall on one side of the furnace. This firing may be either automatic or by hand. Hand firing, while successful in many mills, presents a control that is not very dependable. The use of the human equation is bad practice in work of this nature and while successful in a few instances it is subject to change and the results over a long period of time are far from being consistent. Even with automatic stokers no two boxes, run through the single furnaces, will come out alike in spite of the fact that up to the point of annealing they have come from the same heat and mechanically are treated the same. First and foremost no two masses of steel will correspond exactly in weight, the box will enter the furnace in a little different manner, the initial temperature of the furnace is never the same and weather conditions such as atmospheric temperature affects draft which in turn affects heat distribution. All of these factors favor continuous box annealing which will be discussed in another article.

So far as we are now concerned let us consider giving this box a "full" anneal which will carry it above 1,616 deg. F. From a production basis we must bring the steel up to this temperature as quickly as possible and soak for a definite length of time in order to be certain that every part of the charge has reached this given temperature. In a well regulated furnace the heat gradient will be definite and if this heat cycle is shortened by raising the temperature at a higher or faster rate the result is that the outside and in particular the top of the charge is overheated before the inside and bottom comes up to the predetermined heat resulting in grain growth, under annealing and poor drawing properties.

Careful study of single furnaces will allow, after sufficient experiment, the determination of a heat gradient and soaking period dependent on the mass of steel. A great many annealing furnaces carry only a furnace couple while others carry thermocouples in the box as well. For our detailed discussion we will carry a furnace couple, a couple buried in the top center of the pile of sheets (about 4 in. from the top) and a bottom center couple buried about a foot from the bottom (see Fig. 5). The heat cycle of this box

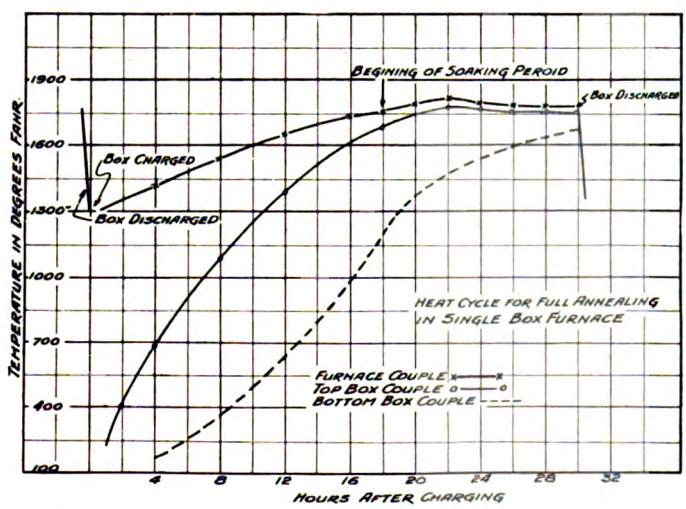

FIG. 6—Heat cycle for furnace couple and upper and lower thermocouples within box during its full anneal.

and the relative temperature for these couples is best illustrated in Fig. 6, explained as follows:

The furnace couple has dropped from about 1,700 deg. F. to 1,200 deg.-1,300 deg. F. following the opening of the doors and the discharge of the previous box so that as we start this particular anneal the furnace couple reads 1,300 deg. F. Let us assume that this box of sheets weighs 35,000 lbs. and our heat gradient calls for the furnace to be at 1,700 deg. F. in 18 hours after charging. The coal is steadily fed into the fire box and the temperature is more or less uniformly raised until we reach the eighteenth hour and the furnace couple reads 1,740 deg. F. At this point our heating period is over, dampers are closed, the

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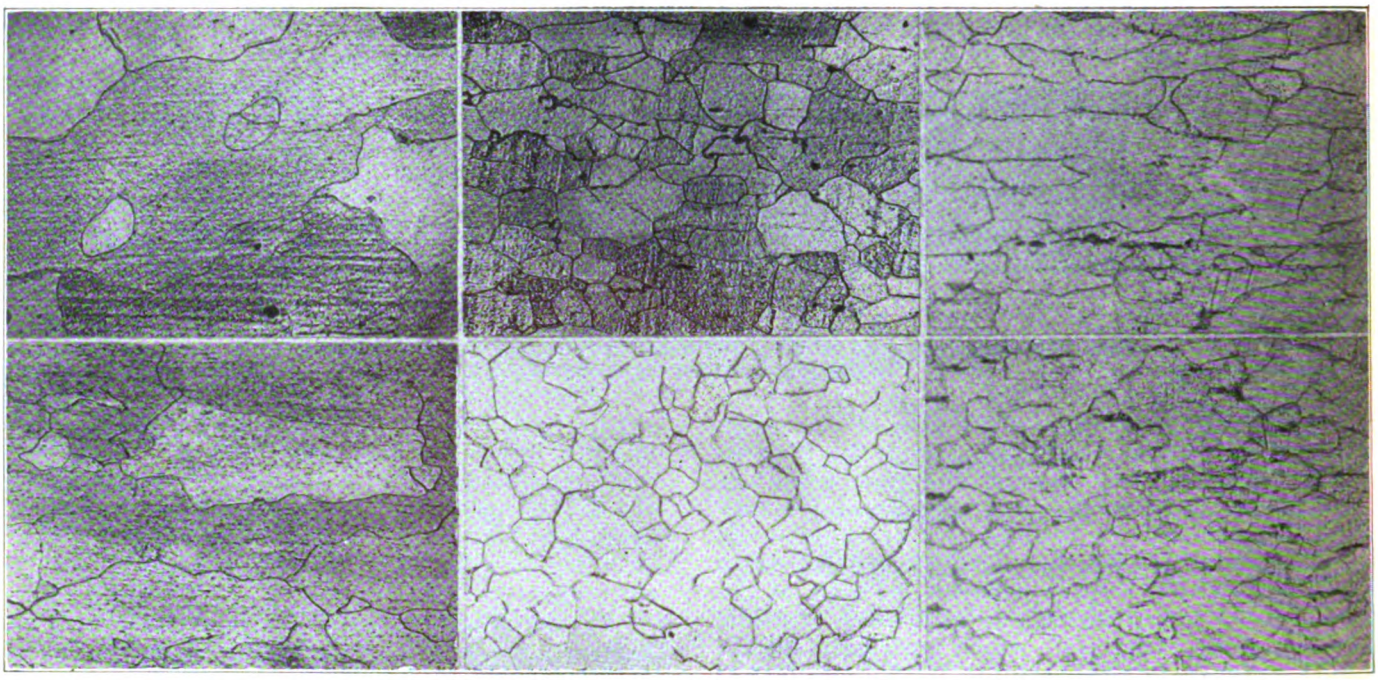

FIG. 7A (upper)—Longitudinal section of sheet from top of pile. Note large grains.

FIG. 7B (lower)—Transverse section of sheet from top of pile. Note large grains.

FIG. 8A (upper)—Longitudinal section of sheet from middle of pile. Note equi-axed structure.

FIG. 8B (lower)—Transverse section of sheet from middle of pile. Note equi-axed structure.

FIG. 9A (upper)—Longitudinal section of sheet from bottom of pile. Note slight elongation of grains also slag inclusions.

FIG. 9B (lower)—Transverse section of sheet from bottom of pile. Note mixture of large and small grains.

X100, etch HNO_3, top edge parallel to direction of rolling.

amount of coal is reduced, and the soaking period begins. While the furnace couple has been working toward this predetermined furnace temperature the top couple of the box has been gradually gaining as the flame has been impinging against and over the top of the box. At the point of soaking this couple has reached approximately 1,680 deg. F. In the meantime the bottom couple has increased very slowly in temperature lagging 600 deg.-700 deg. behind the top half of the pile. This is due to the fact that the majority of the heat present or the hottest part of the furnace is toward the top and it is readily conceived that the upper part of the box is going to absorb this heat.

However, the advent of the soaking period changes the heat distribution. This soaking heat now having no large outlet forces the heat more toward the bottom of the furnace and the heat absorption of the box is now greater. The furnace couple takes on about 100 deg. F. more and gradually drops off as the box absorbs this excess heat. The top couple tapers off in its absorption rate gradually approaching the furnace temperature so that in the last few hours of the soak there is very little difference in their respective temperatures. The marked change which takes place during the soaking is the rapid absorption of heat by the bottom half of the box.

The ratio of absorption rapidly rises and by a careful watching of this bottom couple the box is pulled from the furnace when the bottom half of the pile has passed the desired temperature. At this point there is only a few degrees difference between the top and bottom couples and from a metallurgical standpoint the pile has as even a temperature distribution as can be commercially expected from this type of furnace. The doors are then opened and the box pulled out and allowed to cool until the sheets have reached room temperature which may be from 24 to 48 hours. The introduction of reducing gases into the pot during this cooling prevents scaling of the sheets and produces a sheet bright and free from any oxides. Such sheets are called "deoxidized" sheets and are used on automobile parts which are nickel or chrome plated, as radiator shells and head lamps.

The action which takes place within the box during its anneal is of interest and explains the oxide border and corners present on the majority of sheets for auto stampings. When the cover is dropped over the pile there is a certain amount of air trapped within the box. As this box heats up this air expands, a part of which escapes through the sand seal around the bottom. What remains is broken up into its principal components, nitrogen and oxygen, the oxygen combining with the iron thus leaving a more or less neutral atmosphere within the box. A further increase in the temperature causes the steel to give off gases occluded either in the pickling or from the original ingot. Around the temperature of 1,450 deg.-1,500 deg. F. the carbon in the steel near the surface of the sheet reacts with the oxides previously formed causing the formation of carbon-monoxide gas which in turn ignites. This reaction deoxidizes the sheet and it is now free from any scale. However when the box is withdrawn from the furnace these reactions stop, the gases contract as cooling sets in and a partial vacuum thus created causes the suction of air in the box through the sand seal. The oxygen of the air immediately combines with the hot steel causing an oxide to form on the sheets ranging from straw to blue, in color, depending on the temperature of the steel. This scaling

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is more noticeable on the top sheets which being loosely packed allows the oxygen to creep in towards the middle of the pile. However, in spite of more closely packed sheets in the middle and the bottom of the pile, the oxide creeps in from 2 to 4 in. around the sides with the remainder of the sheets clean and bright. As previously mentioned this air can be excluded by the "deoxidizing" process in which a neutral or reducing gas is introduced while the sheets cool, thus preventing the presence of air.

The box having had a full anneal let us physically and microscopically examine it. The temperatures as recorded through the thermocouples in the box and furnace show that all of the steel should have passed through the upper critical range for a 0.10 per cent carbon steel thus rendering the steel as a solid homogeneous solution which was recrystallized upon cooling.

Furthermore the length of time the steel soaked in the furnace should have been sufficient to relieve hot and cold rolling strains. Sample sheets taken from the top, middle and bottom of the pile show that the annealing has relieved the strains, the sheets show good equi-axed structure, the ductility is passable for the majority of stampings and the sheets are soft. Although this pile is satisfactory for the auto stamping intended, closer examination of the microphotographs and physical tests indicate that the middle test is very good, the top test is coarse grained and softer on the corners and ends due this portion of the box showing the highest temperature while the bottom test shows smaller grain structure and a slightly harder sheet as this portion of the box recorded the lowest temperature of the anneal just exceeding the critical range. Close examination of this microphoto (Fig. 9), indicates that there is a little strain remaining but not sufficient for rejection. A study of Table I and the designated microphotographic plates will bear out the above conclusions. In examining these photos and the table it must be kept in mind the fact that some of these sheets did not come from the same heat or the same part of the ingot. Neither do they take into consideration the elimination of several points of carbon which occurs upon annealing sheet steel. As a general rule this loss of carbon drops from an average of 0.10 per cent before to .060-.085 per cent after the anneal.

Inspection of Box Anneal Sheets

The most important inspection feature that presents itself on box annealed sheets is their "sticking" which is caused by the condition of their surface and the temperature of the anneal. An open surfaced sheet under a high temperature will weld the pile together to a point that it can only be separated by "swording" or hammering. Either practice spoils the surface of the sheets and the last few years has seen this fault overcome in most of the sheet mills by lower annealing temperatures and cold rolling before the anneal.

The slight buckling of the pile as it is picked up by the crane following the uncovering of the box is another inspection defect to be watched. This compact pile of sheets is very soft and if by chance it should buckle or sag slightly this buckling mark will extend through the pile and must be eliminated either by cold rolling or reannealing.

As the majority of auto stampings permit a slight oxide border the presences of this oxide is not so important except as mentioned before where the sheet is to be electro plated. As a general rule the top sheets of a pile are badly oxidized and are usually discarded or shipped as "seconds."

(To be continued)

*Blast Furnace Practice in Natal**

To the American Superintendent the Furnace at This Plant Assumes in Dimensions and Output the Proportions of a Toy but the Practice Is Unusual and Hence Interesting

By J. E. HOLGATE and R. R. F. WALTON

THIS paper concerns principally the blast-furnace plant situated at Newcastle, Natal, owned by the Union Steel Corporation (of S. A.), Ltd., of which the authors are manager and chief chemist respectively. Its object is to describe briefly the development and pioneering difficulties connected with the pig iron industry in South Africa, followed by observations on the character and distribution of raw materials in the Province of Natal and the actual working results of operation over a period of about 15½ months.

As there is only one iron blast-furnace in the whole continent of Africa at the present time, it is interesting to review the main events which have led up to the commercial production of pig iron in South Africa, where the white population does not exceed the combined populations of Manchester and Birmingham. It will be apparent that outputs of iron and steel must, in the first stage, be modest, and then progress as subsidiary industries are established.

The Union Steel Corporation commenced operations in 1913 at Vereeniging, Transvaal, for the manufacture of steel products from ingots made from smelted steel scrap. For several years previously the railways and mines had been inconvenienced by the enormous accumulations of steel scrap, the exportation of which did not pay on account of the long distances to the coast. After long negetiations with many parties, an agreement was entered into for a period of 16 years, whereby the railways supplied their scrap at a low price to the new company, which in its turn was guaranteed the orders for such steel products as the corporation could produce, with due consideration to quality and time of delivery. Owing to difficulties in obtaining new plant, etc., during the war period, it was several years before the Vereeniging Steelworks

*Paper delivered at meeting of the British Iron and Steel Institute, May, 1928.

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were established on a paying basis, but eventually a regular and substantial tonnage of rails, bars, sections, and steel castings was forthcoming, and was quickly absorbed by the railways and mines.

In recent years, however, the supply of suitable scrap has become progressively less than the consumption, and it became obvious that a sound steel industry could not be expanded on a scrap basis only. The manufacture of pig iron on a commercial scale thus became an essential factor. In the meantime, a blast-furnace plant was under construction at Newcastle by a new company called the Newcastle Iron & Steel Company. Owing to lack of capital the plant could not be finished, and arrangements were made to absorb this company into the Union Steel Corporation, thus consolidating the iron and steel interests to the mutual benefit of both companies.

For the pioneer work of laying the foundation of the pig iron industry in Natal great credit is due to Mr. J. K. Eaton, who sank a large amount of his private capital in the original Newcastle concern, as he was convinced that the natural resources of Natal would assure the future prosperity of the industry. He chose Newcastle as the site for the plant on account of its excellent water supply; the carriage on the ore and coke to that town was slightly higher than to the ideal geographical center of the ore and coking coal deposits about 40 miles away, but ample water facilities did not appear to exist at the latter place.

Under the direction of Mr. A. K. Reese, consulting engineer to the corporation, the plant was thoroughly overhauled. Necessary additions were made in the way of improved boiler and water service equipment, etc., while the hearth and bosh of the furnace were enlarged and redesigned on more modern lines. Many other details required serious attention, and after an organization for operation was secured and trained, the furnace was blown in by Mr. Reese on June 18, 1926. The primary object of production was, of course, to supply the necessary basic pig iron for replacing at least 50 per cent of the scrap then being used in the open-hearth furnaces at the Vereeniging Steelworks. Foundry iron would supply the foundries of the Union, replacing the imported brands, and at a price to encourage the more extensive use of pig iron, again in place of scrap, and so promote the more rapid extension of the engineering industries generally within the Union. To this end the Government had previously passed a Bounty Act to encourage the iron and steel industry in the country, whereby a substantial bounty was granted, decreasing in stages as the industry gradually became self-supporting. This was considered to be a better policy than imposing a tariff on imported iron or steel.

Iron Ores of Northern Natal

These ores occur in the Ecca series of the Karoo system, corresponding to the lower Permian rocks of Europe, and in which the coal measures are found.

This series is divided into three natural groups:

1 and 3—The upper and lower Ecca consist largely of black to blue fine sedimentary shales not less than 600 ft. in thickness.

2—The middle Ecca contains the coal measures and ore seams. It consists of sandstone, grits, and shales and is not less than 1,250 ft. thick in the middle of the area. The rocks are nearly horizontal, undulating with a general dip S.S.W. Thin beds of calcareous sandstone are met with, containing about 40 per cent SiO_2 and 45 per cent $CaCO_3$.

The ore beds occur about 120 ft. below the main coal seams, and may be seen over a large area west of Dundee. On the same horizon ore is found in the Utrecht district.

The main source of our iron ore supply is at Prestwick, about 10 miles NE. of Dundee and 58 miles by rail from Newcastle. This has been proved to be an extensive bed lying very slightly off the horizontal, with occasional slight undulations, through a long ridge of hills. The outcrops round this bed may be traced for several miles, and in 1925 it was decided to open up on the Prestwick farm, where the outcrop ore appeared to show the greatest expanse. Here it was easily uncovered and served as the original supply of ore for the blast-furnace (about 30,000 tons). This outcrop ore consisted of a hydrated oxide of iron of the following average analysis:

Oxide Outcrop Ore (Prestwick).

	Per cent
Iron	49.25
SiO_2	8.00
Al_2O_3	4.20
CaO	0.50
MgO	0.45
Mn	0.43
P	0.15
S	0.04
Loss on ignition	15.00

The Union Steel Corporation constructed a railway line about 7 miles in length to connect with Tayside Station, at a cost of over £25,000, and established a properly equipped mining camp, as there was every indication that the area would yield a permanent supply of ore.

In the meantime an adit was driven into the hill which contained the main body of ore, and arrangements were made for intensive development. Within 30 ft. of the surface the deposit was found to consist of a uniform body of ferrous carbonate, black in color and very dense. The bed varies in thickness from 3 ft. to over 10 ft., but the line of development lies now in the direction of the thicker portion, which appears to be unlimited in extent. Above the carbonate ore there exists a seam of shale about 10 to 12 in. thick covered by another thin band of anthracite coal 6 in. thick. The roof is a very sound sandstone and requires no timbering.

The ore has been found to be very uniform in analysis in all directions, the following being average analysis at different points:

Analyses of Prestwick Carbonate Ore.

	Date				
	April 1926 %	Oct. 1926 %	Nov. 1926 %	Jan. 1927 %	Oct. 1927 %
Iron	42.80	40.28	41.02	40.03	41.20
SiO_2	5.50	5.15	4.45	5.60	6.30
Al_2O_3	2.60	2.40	2.55	3.00	2.70
CaO	0.75	0.70	0.70	0.80	0.50
MgO	0.65	0.20	0.30	0.30	0.20
Mn	0.44	0.45	0.50	0.49	0.56
P	0.14	0.13	0.12	0.13	0.14
S	0.14	0.18	0.15	0.15	0.14
Loss on ignition	28.10	33.35	31.90	31.65	30.90

As will be shown later in more detail under furnace operation, a very important feature of this large

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ore body is the fact that it contains about 5 per cent of free carbon in a very fine state of division. This renders the ore-self-calcining and also promotes coke economy in the furnace, where it is easily reduced, partly through the disintegrating effect of heat on the laminated lumps of ore.

This ore may be classed geologically as a siderite of sedimentary formation, and it is doubtful if another such body of similar purity and uniformity has yet been exposed in any other part of the world. The outcrop is softer in character, being hydrated oxide of iron of a limonite character, obviously produced by prolonged atmospheric action on the originally exposed carbonate. It is very interesting to observe at the mine how the light brown oxide gradually merges through the intermediate stages into the primary stage of dense black carbonate underground.

The main driving adit extends now close on to 2,000 ft. into the hill, and other adits are being developed with mechanical haulage to enable large tonnages to be handled. Coal-mining principles have been introduced, utilizing the pillar-and-stall system. At the present time about 300,000 tons of pure ore have been blocked out in pillars, the average thickness of the bed being in the neighborhood of 6 ft. Even supposing the whole ore body only averages 2 ft. 6 in. in thickness, it is computed that the properties over which the Union Steel Corporation hold the rights contain not less than 60,000,000 tons of ore. This figure has been endorsed by Mr. F. A. Steart, a well-known mining engineer and geologist in Natal. Assuming that only 10,000,000 tons are availiable or capable of economical extraction, this quantity would be sufficient for an output of 150,000 tons of pig iron annually over a period of about 27 years.

Although Natal has not been thoroughly prospected for iron ore deposits, the following are of interest owing to their quality, and are an encouragement for further prospecting.

Rodell's Farm—This ore is a surface deposit of hydrated oxide of iron situated about 8 miles from the Prestwick deposit and near the railway. The overburden varies from a few inches to 2 ft., and the ore varies from 18 in. to 36 in. in thickness. The total quantity in sight is estimated at about 200,000 tons. Approximately 22,000 tons have been smelted at Newcastle in admixture with Prestwick carbonate ore, with satisfactory results.

A typical analysis of Rodell ore is as follows:

	Per cent
Iron	50.05
Silica	5.95
Alumina	4.00
Lime	Trace
Magnesia	Trace
Manganese	0.57
Phosphorus	0.081
Sulphur	0.025
Moisture	10.00

This small deposit was very useful in the early stages while development was proceeding at Prestwick, as the ore is loaded into truck very cheaply.

Hezledene—This property is situated about 10 miles east of Dundee and 7 miles from the railway. The ore is a massive hematite rich in iron and low in phosphorus. So far as is now known the extent is small, probably about 70,000 tons. It appears to be a surface deposit averaging 5 ft. in thickness, and can be worked open-cast, the overburden being only 1 or 2 ft. A few hundred tons of this ore have been delivered on rail by ox-wagon, and smelted at Newcastle. The average analysis of these deliveries was as follows:

	Per cent
Iron	63.45
Silica	1.85
Alumina	0.35
Lime	0.45
Magnesia	0.35
Manganese	0.30
Phosphorus	0.029
Sulphur	0.048
Loss on ignition	4.00

Dick's Farm (near Utrecht, about 20 miles from Newcastle)—This is another small surface deposit of soft brownish-red ore which for some years has been worked in a desultory fashion for the manufacture of oxide paint. Samples of harder ore picked out analyzed as follows:

	Per cent
Iron	55.10
Silica	8.75
Alumina	2.95
Lime	0.85
Magnesia	0.44
Phosphorus	0.122
Sulphur	0.020
Loss on ignition	7.35

Palmyra—This is a curious deposit of calcareous ore situated near the Dundee-Vryheid Railway line, 10 miles east of Prestwick. It is farther under the surface, and boreholes have proved a quantity of approximately 100,000 tons. The analysis is as follows:

	Per cent
Iron	28.20
Silica	0.98
Alumina	0.85
Lime	25.10
Magnesia	6.45
Manganese	0.61
Phosphorus	0.13

If the quantity should prove greater, it will be worth while opening out and using it with the Prestwick ore in place of limestone or dolomite as a flux.

(To be continued)

World's Finest Wire Cloth

A world's record has been established by the Newark Wire Cloth Company of Newark, N. J., by making a wire cloth having 160,000 square openings per square inch. It is the finest wire cloth ever made.

In other words, it is a "400 mesh" wire cloth with 400 parallel wires per inch of width running each way, at right angles.

400 x 400 = 160,000 openings
1,000,000 divided by 160,000 = 6.25

Therefore in a piece of the wire cloth slightly more than 6 sq. in. in area, there are 1,000,000 holes. Or, to be exact, in a piece only 2½ in. square there are 1,000,000 square microscopic openings.

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The POWER PLANT

A Modern Power and Blowing Plant*

This Review Is Thorough and Comprehensive, Bringing Out Clearly the Advantages of Modern Power Equipment that Fully Justify Installation Costs

By WILFRED SYKES†

THE generation of power in steel plants has been in many cases largely of haphazard growth. Originally relatively small d.c. generating stations were installed to supply auxiliary power for mills and, as the demands increased, additions were made from time to time with the result that, as a whole, they were relatively uneconomical. In a modern plant with blast furnaces the generation of power is largely tied up with the utilization of the surplus blast furnace gas. As the plants have devoloped and the main drives have been electrified, the question of power supply has become relatively more important. In general, as the generation of power is an auxiliary operation and a power plant is not a direct producing unit, it has not received adequate engineering attention, but has been rather looked upon as a necessary evil and subordinated to the more important work connected with the producing units. The necessity of exploring every means to reduce operating costs has directed attention to such auxiliary operations, and the provision for economic generation of power and electrification of mills has been one of the factors which has enabled such costs to be reduced.

In 1923 the Inland Steel Company began the construction of a new power and blowing plant adjacent to the blast furnaces to use the blast furnace gas to a better advantage and to supplement the existing electric supply. The newer mills were electrically driven, power being obtained from a 20,000 kw. turbo-generating station, supplied with steam from coal-fired boilers. Extensive additions were then being made to the plant and the electrification of the older steam-driven mills was contemplated. There were installed three 12,500 kva. turbo-generators and five turbo-blowers for the four furnaces. In addition to supplying a.c. power for general plant use, the station also supplies d.c. for the operation of the docks, blast furnaces and coke plant, and for this purpose four 1000 kw., 250-volt rotary converters were installed.

In addition to supplying power and blowing the furnaces, part of the service water required in the plant is supplied by pumps located in the power house. These pumps take the water after it has passed through the condensers of the blowers and turbo-generators, and deliver it to the mains at a pressure of 40 lbs. per square in. The pumps installed have a capacity of 90,000,000 gals. per day. Compressed air is also supplied to the blast furnaces at a pressure of 100 lbs. per sq. in., two 500 cu. ft. compressors being installed for this purpose.

To supply the condensing water required for this power house, a pumping station was built at the lake front, which has a total capacity of approximately 135,000,000 gals. per day. The usual amount pumped is approximately 60,000,000 gals. per day in winter, and 90,000,000 gals. per day in summer. This water is carried from the pumping station to the power house through a cast iron pipe line 5 ft. in diameter, and about 1,600 ft. long, the head of the pumps being 30 ft. The water not repumped to the service line flows back to the lake.

Load Conditions

The demand for electric power naturally varies considerably. The total momentary demand of the plant will reach 40,000 kw., and for a period of 24 hours the load has averaged over 31,000. In general, the peak loads will reach about 36,000 kw., and the average daily load will run between 26,000 and 28,000 kw. On Sundays the load is practically constant at 11,000 to 12,000 kw.

Of the total power generated in the plant approximately 90 per cent is supplied by the power house utilizing blast furnace gas, and the older equipment supplied from coal-fired boilers is used to assist in carrying peak loads and also to help out when the supply of blast furnace gas is reduced for any reason. As previously mentioned, the new generating station is provided with converters for supplying power to the blast furnaces, docks and coke plant. In summer, when raw materials are being unloaded, the d.c. load will average about 3000 kw., with peaks of over 4000 kw., and in winter, when there is no unloading, this d.c. load will average between 1800 and 2000 kw.

While in general the power house will carry about 90 per cent of the total load, there are short periods when furnaces may be casting or shut down for minor repairs. It is desirable to maintain the load on this station, and for this purpose auxiliary oil firing has been provided. Generally oil firing is not used for periods of over one-half hour at a time, and total consumption of oil for this purpose is relatively small. A light oil is used so that it can be put on the boilers instantly without preheating or other preparation. Steam is used for atomization and the air is supplied by motor-driven propeller-type blowers at each burner.

In the boiler room there are installed four 1500 hp. bent tube V-type, four-drum boilers, each having

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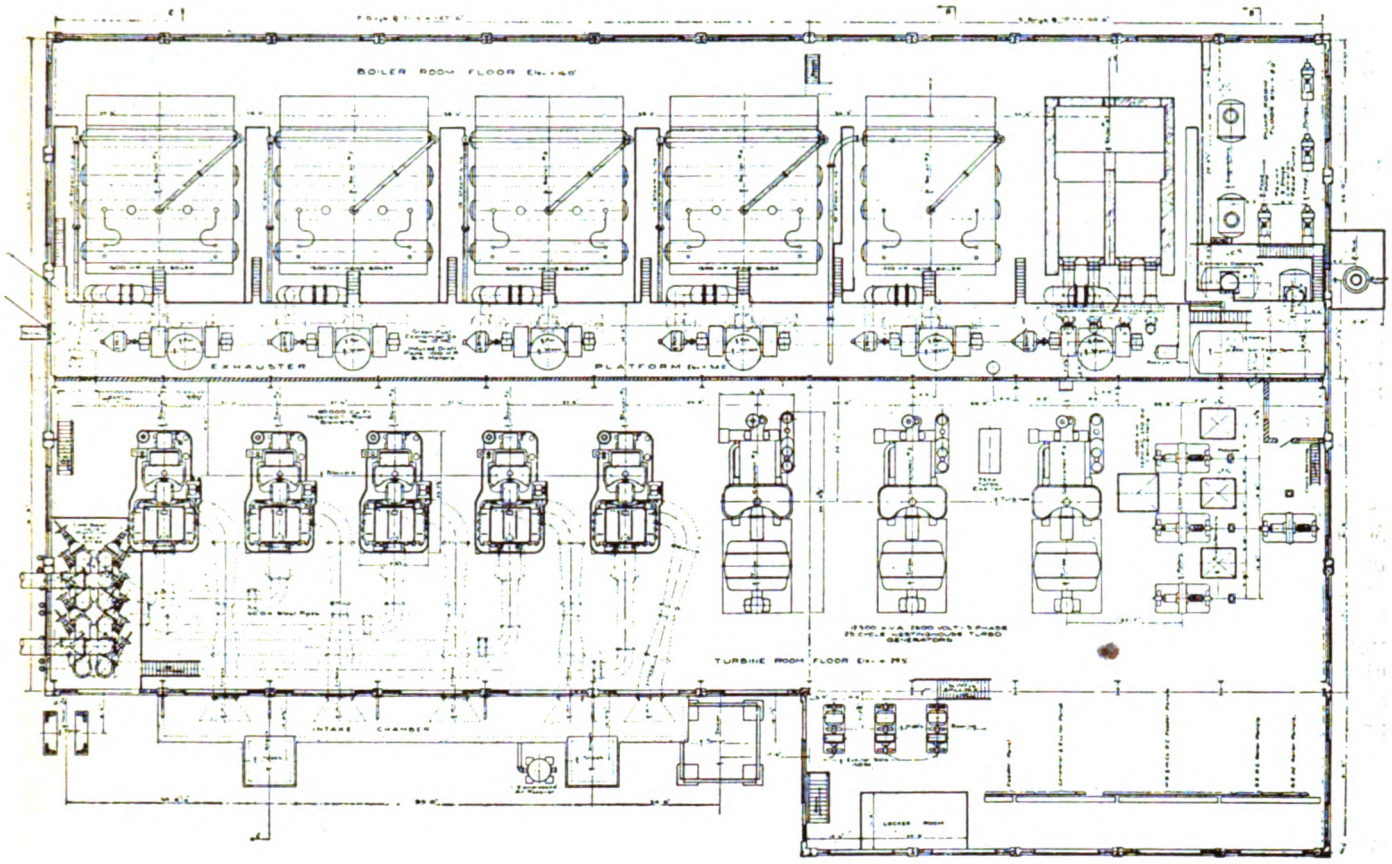

FIG. 1—Plan view of station.

14,918 sq. ft. of heating surface. These boilers also have integral two-drum economizers with vertical tubes. The economizers have a surface of 7,850 sq. ft. They are also provided with superheaters located in the first bank of boiler tubes. These superheaters each have 1,610 sq. ft. of surface. The volume of the combustion space of these boilers is 10,700 cu. ft. each. There are also two 1200 hp. boilers of the same type having 12,045 sq. ft. of heating surface, the economizers having 6,740 sq. ft. and the superheaters 1,290 sq. ft. The combustion space of these boilers is 8,750 cu. ft. All boilers are designed for a maximum pressure of 305 lbs. per sq. in., at which the safety valves are set, and deliver steam at about 200 deg. superheat. They are normally operated at about 275 to 280 lbs., so as to allow a margin between the normal working pressure and the point at which the safety valves lift, to provide for sudden fluctuation in load which might cause the boilers to blow off and thereby add to the make-up water required.

No raw water is used in the boilers. The condensate from the surface condensers of the turbo-blowers and turbo-generators is returned to a feed tank and any make-up required is supplied by a double effect evaporator which has a capacity of approximately 10,000 lbs. of make-up water per hour. The water from the feed tank flows through two de-aërating heaters; these heaters condensing the exhaust steam from the feed pumps and the vapor from the evaporators, which is returned to the de-aërating heaters through a trap. The temperature of the feed water is raised approximately 60 to 70 deg. F. by these heaters and the oxygen content of the water is reduced to .05 c.c. per liter or less. After passing through the de-aërating heaters the water is pumped to the boilers by turbine-driven centrifugal pumps, the flow to each boiler being controlled by duplicate feed water regulators. In the economizer section the temperature of the feed water is raised from approximately 160 deg. F. to about 350 to 400 deg. F.

As steam leaves the superheaters it passes through non-return valves at the boilers to the main steam header in the boiler house. Where the steam lines from the boilers connect to the header, electrically operated valves are provided, which are so arranged that they can be operated from a point outside of the boiler house in case of emergency. From the main header, branches are taken to the turbines and there is also a branch to supply the auxiliary steam for the operation of the evaporators, feed pumps, etc. The main header is subdivided and a by-pass provided so that in case of serious trouble only a part of the header will be out of operation at any one time. The general arrangement of the boiler room and turbine room is shown in Fig. 1.

Turbine Room

The three 12,500 kva. turbo-generators are connected to the main steam header with short bends to provide for expansion and a separator is installed ahead of each unit to trap any water which might be carried over from a cold main. The turbo-generators are designed to carry about 11,500 kw. at 270 lbs. steam pressure, 200 deg. superheat. The power factor of the station is usually about 90 per cent or higher, and the turbines are designed so that the corresponding capacity of the generators can be utilized. These machines have at times carried up to 12,000 kw. each. Power is generated at 2400 volts, 3 phase, 25 cycle.

Immediately below the turbo-generators are the surface condensers, a copper expansion joint being provided between the turbine and the condensers. The

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turbo-generators and the condensers are carried on a structural steel frame supported by a flat concrete slab. The concrete was laid on sand; no piling was used under the machines. The total pressure per square foot averages about 1500 lbs., and no appreciable settlement has been noted in the foundation since installation. The condensers are of the two-pass type, with 1 in., 18 gauge tubes, 18 ft. long. The tube sheets are of Muntz metal and the tubes of Admiralty metal.

To remove the air from the condenser, duplicate two-stage air ejectors are provided, which have inter and after condensers, the condensate from which is returned to the condensers through a water leg. For the removal of the condensate from the condensers duplicate motor-driven pumps are provided, which discharge into a header leading to the main feed tank.

The turbo-blowers, which have a capacity of 60,000 cu. ft. of free air per minute against a pressure of 30 lbs., are driven by turbines having a maximum output of 7900 hp. each. These turbines are designed to operate on 270 lbs. steam pressure and 200 deg. superheat; and under maximum volume and pressure conditions, run at approximately 3000 rpm. The turbo-blowers are carried on structural steel frame, which also supports the condensers, an expansion joint being provided between the condenser and the turbine.

The condensers have a total surface of 5300 sq. ft. and are provided with ¾-in. tubes, 16 ft. long. These condensers have divided water boxes so that it is possible to clean half of the condenser while the blower is in operation. In general this is not necessary, as a spare blower is practically always available.

The air to the turbo-blowers enters the suction side through a 54-in. inlet main in which there is a Venturi tube. The regulation of the air flow is controlled from this tube through a bell connected to the governing gear of the turbine driving the blower, and connections are also taken to the recording gauge and the indicator which indicates the air flow. The governor gear on the turbine is designed to maintain constant flow independent of pressure variations and under ordinary operating conditions the volume will not vary more than 300 or 400 cu. ft. per minute from the value at which the governor is set, when operating at any range up to 60,000 cu. ft. per minute. The turbines driving the blowers are provided with a hand-operated valve for quickly checking the volume discharged, independent of the governor, when the furnaces are casting. This valve is also arranged so that it can be operated by a small motor from a central control board if desired.

Due to the large volume of air required for the blowers and the desirability of reducing noise to a minimum, the air is taken through the inlet pipe from a lean-to outside the power house. This lean-to is supplied with air from two rectangular stacks with louvres, which prevent rain from entering the intakes. Any water that might be carried down the stacks has an opportunity to separate out in the lean-to before it enters the blowers.

The discharge of the five blowers is taken to a nest of valves in one end of the turbine room. These valves are so arranged that any of four blowers can be used on either of two furnaces and the fifth blower can be used on all four furnaces. The discharge pipes are 36 in. in diameter, but, to reduce the space required and the cost, 24-in. valves are provided for controlling the connections between the blowers and the furnaces. There are tapered connections from the 36-in. main to these valves and the loss in pressure through the valves is relatively small. Tests made indicate that there is a recovery of 81 per cent of the velocity head through the 24-in. valve, which is reconverted to static pressure. These valves are all electrically operated from the central control board for the blowers, so that any set-up can be made in a very short time, or in cases of emergency one blower can be used on two furnaces to maintain pressure until the spare machine can be started.

For starting up a spare machine it is necessary to provide for discharging a certain quantity of air to prevent pumping, and 8-in. electrically operated valves are provided for this purpose, the discharge through these valves being sufficient to prevent this condition. When the blowers are connected to the furnaces these valves are closed. In addition relief valves are provided to discharge air to the atmosphere when the pressure on the cold blast line exceeds a predetermined value. These valves operate automatically. Between the blowers and the nest of valves there are provided check valves to prevent any back flow of gas or any excess pressures being imposed on the blowers by explosions or slips in the furnaces.

A central control board is provided for mounting the controls for the various electrically operated valves in the air lines, with the necessary indicating lights; and also the control for the valves used to check the blowers during casting. On this board is also mounted the signal system used in conjunction with blast furnaces with the necessary lights and audible signals. This signal system is so arranged that when the control handle at the blast furnace is thrown to a certain position, a lamp will be lighted on the control board, and there will be an audible signal operated at the blast furnace and at the control board. When the operator at the blowers throws his handle to a corresponding position, the light is extinguished and the audible signal stops at both places. In this way the blast furnace blower knows that his signal has been correctly received by the blower operator. On this board is also mounted a combined pressure and volume recorder, the chart from which can be used for checking operations.

For supplying condensing water to the condensers of the turbo-blowers and turbo-generators, the 5-ft. main from the pump house connects to a header in the basement of the boiler room and, from this header, connections are taken to the various condensers. There are single connections to the turbo-generators and double connections to the turbo-blowers on account of the divided water boxes. Each connection is provided with an expansion joint and a valve located in the basement of the turbine room regulates the flow to each condenser. The discharge from the condensers flows into a trench below the basement floor. One end of this trench forms a sump from which the water for service pumps is drawn and the excess flows over a weir at the other end and returns to the lake.

An oil purification system is installed to condition the oil from the turbo-generators and turbo-blowers. These machines are piped up so that the oil can be drained to a dirty oil tank in the basement, from which it is passed through a centrifugal separator after which it is pumped to the clean oil tank. The clean oil tank is elevated so that the reservoirs at the turbines are filled by gravity. Any overflow from these reservoirs will return to the dirty oil tank. With this system the

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total consumption of oil by the turbines is only one or two barrels per year. Changing oil involves very little work and the treatment is simple, so that the oil in the machines is kept in first class condition at all times.

Switchboard

The power generated by the turbo-generators is carried by cables to a duplicate bus structure located in the basement of the switchboard lean-to, which is adjacent to the turbine room. This main bus structure is so arranged that the switches may be worked on without interfering with the operations of the machines, and from this basement the various cables distributing power to the plant are run. At one end of the main bus structure there is provided an auxiliary bus structure which is connected to the main bus through a reactance. This auxiliary bus is used for supplying power to the rotary converters, exciters and pumps. Immediately above the bus structure room, is located the main switchboard for controlling the generators and the feeder circuits, as well as the exciters. Adjacent thereto is a d.c. switchboard for controlling the output of the rotary converters and distributing the power to the blast furnaces, coke plant and to the auxiliaries in the power house.

The general operating results of the station during the month of December, 1927, are shown by the following tabulation:

Operating Results December, 1927

Total steam generated		259,362,000 lbs.
Steam to turbo-generators		172,454,000 lbs.
Steam to turbo-blowers		76,333,000 lbs.
Steam to auxiliaries		6,905,000 lbs.
Steam to soot blowers		3,670,000 lbs.
Total gas consumed		4,559,400,000 cu. ft.
Average Btu. per cu. ft. in gas		90.3
Total oil used		4,500 gals.
Average Btu. per gallon oil		140,000
Percentage of make-up water from evaporators		1.42%
Distribution of Steam to Auxiliaries.		
Boiler feed pumps	4,098,200 lbs.	
Evaporators	1,886,800 lbs.	
Evaporator feed pump	27,200 lbs.	
De-aerators	892,800 lbs.	
Total	6,905,000 lbs.	
Kilowatt hours generated		14,310,000
Kw. hrs. to exciter M.G. sets	104,100	
D.c. power for station auxiliaries 249,520 kw. hr. equivalent a.c.	271,500	375,600
Net output of station, kw. hrs.		13,934,400
Distribution of D.C. Power for Auxiliaries.		
Turbo-generator condensate pumps, kw. hrs.	25,845	
Turbo-blower condensate pumps	14,570	
Repumping condensate from storage	6,100	
Boiler induced draft fans	180,685	
Lighting	22,320	
Total kw. hrs., d.c.	249,520	
A.c. power used for auxiliaries		2.62%
Steam consumed by turbo-generators per kw. hour generated		12.04 lbs.
Steam per kw. hr. including all auxiliaries		12.56 lbs.
Btu. per kw. hr. including all auxiliaries		19,880
Pig iron produced		62,680 tons
Pounds of steam used by turbo-blowers, excluding auxiliaries, per ton iron produced		1,216

During this time only three furnaces were in operation as the fourth was being rebuilt; but these figures represent approximately the average results obtained from this plant. This tabulation also shows the distribution of power to the auxiliaries. All quantities given in this tabulation are measured.

The force required for the operation of the station is as follows:

	Men per turn	Total
Boiler Room.		
General foreman, part time	.	1
Turn foremen, in direct charge of boilers and boiler auxiliaries	1	3
Water tenders, to regulate gas and watch boilers	3	9
Repair men, for repairs and as extra help when required	.	2
Sweeper, for cleaning and carrying supplies	.	1
Turbine Room.		
Engineer in charge of turbo-generators	1	3
Turbo-generator engineer helpers	1	3
Turbo-blower engineers	2	6
Turbo-blower engineer helpers	2	6
Pump engineers for all pumps and air compressors	1	3
Pump engineer helpers	1	3
Switchboard attendent	1	3
Switchboard attendant helper on miscellaneous electric work	1	3
Mechanical repair foreman, part time	.	1
Mechanical repair helper and relief engineer	.	1
Electrical repair men and relief switchboard operator, part time	.	2
Sweeper, turbine room	.	1
Test engineer, part time	.	1
General electrical foreman, part time	.	1
General mechanical foreman, part time	.	1

Operating Cost

The following are the operating costs of this station for the year 1927:

Total power generated, kw. hrs.		172,676,400
Total power cost		$ 761 826
Average operating cost per kw. hr.		$ .00441
Tons pig iron produced, gross tons		811,417
Total cost of blowing		$ 397,895
Cost of blowing per ton iron produced		$ 0.49
Credit for gas used from blast furnaces at power house	$956,925	
Credit for gas used under boilers for steam used for other purposes	$105,585	
Total credit to blast furnaces for gas		$1,062,510
Credit per ton iron produced		$ 1.31
Net credit to blast furnaces after deducting cost of blowing from total credit per ton iron produced		$ .82
The gas credit to the blast furnaces was based on being the equivalent of 278,874 tons of coal, the value of which was $3.81 per ton.		

In comparing the cost of this combined generating and blowing plant with a simple generating plant, each of the blowers can be considered as being equivalent to a 5000 kw. turbo-generator, as the capacity of the turbines and cost is approximately the same as such electric machines. Consequently the total capacity of this station can be considered as equivalent to about 59,000 kw. The total cost of the station, including pump house, pipe line for circulating water supply, transmission lines to the pump house, the air compressors and service water pumps, was $3,452,766, or equal to $58.50 per equivalent kw. installed. If this were purely a generating station the cost would have

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been less as the number of units involved would have been smaller.

The conditions involved in designing this station were somewhat different to what will exist in designing a public utility plant. An endeavor was made to balance up cost of construction with operating efficiency, to obtain the lowest total operating cost, keeping in mind that such an operation in a steel mill is purely an auxiliary one and only incidental to the main purpose of such a plant. The load factor of a station of this kind averages approximately 50 per cent under the conditions that we operate, and it is essential that it should be simple enough that it will give continuous service. A failure of power supply for even a very short period, while of no particular importance from a mill standpoint, is extremely serious when it causes a failure of the water supply, as the damage that can be done at the blast furnaces, open-hearths, heating furnaces and coke plant, can be of a very serious nature, and which would involve damage which might put the plant out of operation completely for a considerable period of time. It was, therefore, not attempted to obtain the highest possible operating efficiency when measured in Btu. per kw hour, but rather to strike a balance between the cost of installation, simplicity and reasonable operating efficiency. As it will be seen from the preceding tabulation, the plant generates power with less than 20,000 Btu. per kw. hour; at times it has operated with less than 19,000 Btu. per kw hour, and the figures in the preceding tabulation are not by any means the most favorable that have been obtained, but probably represent about the average throughout the year.

The station since its completion has been free from major failures or operating troubles of a serious nature, and the maintenance cost has been very low. The boilers are usually kept on a line for six months at a time when they are taken off for inspection by the insurance inspectors, at which time any accumulated dirt on the tubes or in the combustion chambers is removed. The interior of the boilers is very good. There is no pitting or corrosion of the economizer drums or tubes, which indicates that the de-aërators have efficiently removed the oxygen from the feed water. The only time that there has been any cleaning of the interior of the boilers was when there was a leak of raw water through one of the condensers, which was not discovered for some time. Since a leak test of the feed water has been made there have been no deposits of any kind in the boilers. Condensate from each condenser is tested frequently to determine if its electric resistance is above a certain value. This is a simple test which only takes a few minutes and has proven entirely satisfactory.

It is believed that the figures given in this paper indicate clearly that under present day conditions a steel plant can no longer afford to operate old equipment either for the generation of power, blowing of furnaces, or driving of the mills. The results obtained from this installation have shown a very substantial reduction in the operating cost which amply justifies the expenditure.

*Steel Plant Waste Heat Boilers**

Conditions Affecting the Economical Operation of Waste Heat Boilers Are Reviewed and the Circumstances that Justify Any Certain Installation Are Discussed

By R. H. STEVENS†

PART II

SINCE superheaters, when producing up to approximately 125 deg. F. superheat, have come to be viewed almost as an integral part of the boiler itself, its installation in connection with waste heat boilers presents no exception to the condition that, if the gases coming to the installation are not of sufficient temperature to permit the slight reduction caused by this apparatus, the probabilities are that waste heat boilers themselves could better be replaced with recuperators or the like.

Because of the scattered location of waste heat units, superheating has greater importance, in reducing or eliminating the heavy condensation in steam lines, as the point of consumption is more distant.

Economizers also place additional load on the fan, due to the increased resistance established.

An accurate distinction between too much and too little heating surface in both the boiler and economizer may reduce or eliminate this objection, but it is quite probable that the fan, after all, will have to bear the penalty of erroneous calculations.

With the aforementioned tendencies toward higher steam pressures and consequent high temperature of gases leaving the boiler, the field broadens slightly for the recovery of heat at this point. However, recuperators or preheaters may be used to better advantage.

Water-Sealed Reversing Valves and Flue Losses

If waste heat boilers are to produce the best results, every attempt must be made to conserve the heat between the checker chambers and the boiler.

Observations made at water-sealed valves have shown from 110 deg. to 170 deg. F. drop in temperature of the gases passing through them.

Also brick flues between reversing valves and the stack have shown a similar drop, thus making an average total drop of 280 deg. F. between the end of the checkers and the stack, the greater portion of which can be retained for use at the boiler by efficient dry-sealed valves and by insulating the gas flues.

This feature has been the occasion of probably as much discussion as any other one in connection with

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waste heat boilers. Its far reaching effect includes reducing the gas temperatures, the boiler efficiency and the drafts, with the added feature of increasing the load on the fan, as well as assisting in producing explosion.

About the only method available for determining the amount of infiltration is comparison of gas analyses at different points along the flues; and before and after the boiler. The sampling for such analyses should be made only by those who realize the value of the results to be obtained.

Numerous liquid or plastic coatings for boiler settings and flues have been used with various degrees of success; but under best conditions of operation, we must probably expect to have air infiltration of 10 per cent from fire-tube and 20 per cent from water-tube boilers.

When we consider that the draft within the setting at a waste heat boiler may run from 2 in. to 6 in. H_2O pressure, instead of ¼ in. to 1.5 in. as in the ordinary boiler, we can understand why heavy infiltration is likely to exist.

Where any form of dry-sealed reversing valves is used there is also a possibility of air leaking from the air checkers backward into the gases going to the boiler.

Type and Design of Boiler

We believe that up to the present time the majority of boiler installations have been made with the water-tube type and have included the horizontal, inclined and vertical arrangement of tubes. More recently there has been a trend toward the fire-tube type. Results obtained therefrom lead one to believe that the economical performances of such units compare very favorably indeed with those of the former type.

There seems to be a tendency among waste heat boiler builders to use a smaller diameter tube than the customary 4-in. tube used in the construction of the standard boiler, and consequently to reduce the gas passages around the tubes in water-tube boilers and through the tubes in fire-tube boilers. This change, no doubt, is in order to increase the rate of heat transfer from low gas temperatures. In the case of the fire-tube type, these small tubes become the gas passages and greater necessity is created for efficient blowing of the dust.

Whatever the type selected for waste heat work, that boiler must receive the same serious consideration as any fuel-fired boiler, and must be based upon heat transfer induced by convection and not by convection and radiation.

Without the characteristic heat transfer induced by radiation, the waste heat boiler becomes a modified form of recuperator, and as such, circulation over the entire surfaces of both sides of the tubes becomes an all important feature. Of course, in the recuperator these circulations may not necessarily be self-induced in order to produce satisfactory results, but a waste heat boiler (or any other boiler) must positively depend upon self-created circulation.

Settings—As the greatest loss in efficiency on a waste heat boiler is caused by air infiltration through the settings, the boiler best protected against this will give best results and in this respect the fire-tube boiler would seem to be preferred. The fire-tube boiler is also easily kept free from dust while in service either by mechanical or hand blowing.

Heat transfer and maintenance—Just as proper provisions must be made for maintaining in a clean condition the gas side of the flues, so must the water surfaces be maintained in proper condition.

In boilers of the fire-tube type, this feature is more serious, because of the inaccessibility of the outer tube surface for cleaning.

Several systems are obtainable for the proper conditioning of water for this particular purpose, but the superiority of one over the other is probably yet a matter of opinion and operating conditions attending such an installation.

With boilers of the water-tube type the matter presents no features uncommon to the performance and requirements of the ordinary boiler plant.

Drafts to be Maintained

The minimum draft permissible in any installation will be that which prevents the blowing outward of the gases at the furnace doors. Consequently the necessary draft is probably better determined by measurements of its intensity in the downtakes from the furnace, rather than at the entrance to the boiler, or in case of no boiler, in the stack. When the draft gauge at the entrance to the boiler reads higher when the gases coming from one end of the furnace produce a blowing out at the doors, than when coming from the other end they produce no blowing out at the doors, it is ample evidence that the checkers on the first end are plugged. Therefore, drafts taken at the entrance to the boiler, unless properly considered, may lead to confusing and contradictory conclusions, and it is recommended that while permanent gauges installed ahead of the boiler still be retained, provisions for the periodic observations at the downtakes be also included in the installation and operation of the boiler and furnace; the former to determine and maintain the proper conditions at the hearth, and the latter, in conjunction with the former, to ascertain the conditions existing in both the checker chambers and the boiler.

Drafts being an all important feature in the performance of the furnace, the boiler must be operated and maintained in such a manner as to give the furnace every advantage, or at least not to impose any condition that would interfere with its operation.

Certain temperatures existing in the gases entering the base of the stack before interposing a boiler inherently produce certain draft intensities. Consequently it is absolutely impossible to rob these gases of any of their temperature and preserve the same draft. Decreasing these temperatures from 1,100 deg. to 500 deg. F. by any means whatsoever means a reduction in draft of approximately 35 per cent outside of the reduction due to the resistance caused by the apparatus producing these temperature drops.

It is well established that high velocities of heated gases passing over conducting surfaces divide the gases into many small and turbulent streams, and thereby increase the rate of heat transfer. This also increases the draft demands, which must be met to procure the necessary high efficiency required. Further demands upon the draft will depend entirely upon the design of the boiler itself and the connections thereto. Whether or not the summation of these demands can be furnished with natural draft, or require a fan, depends upon plant conditions, but in general,

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the high limit of draft intensity possible with a justifiable height of stack falls short of meeting these demands.

In ordinary water-tube boilers, we understand that the gas flow per square foot of flow area runs between 3,000 and 4,000 lbs. per hour, whereas with a fire-tube unit these amounts run nearer 10,000 lbs. in the same time, corresponding approximately to 27 to 36 ft. per second and 90 ft. per second respectively. This being true, it would seem that the resistance of the latter would be something like four times that of the former, but such, from our observations, has not proved to

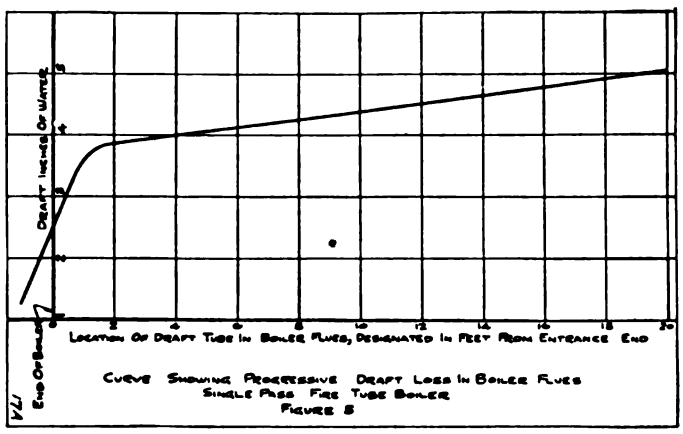

FIG. 5—Curve showing progressive draft loss in boiler flues of a single-pass fire-tube boiler.

be the case. As shown in Fig. 5, a probable explanation for this may be found in the fact that the resistance through the fire-tube type is due only to entry loss and friction on the sides, while that set up in a water-tube type, especially if the tubes are staggered, with the flow of gases across them, is due to the continued striking of the tube or the forced change of direction, as well as to the friction. Where the gases flow along the tubes in a water-tube type, two or more passes are necessary, and if vertical, one or more must be downward, or counter to the natural flow.

The summation of all the draft losses in the water-tube type may be, and no doubt is, less than those of a single-pass fire-tube type, but they are not reduced in the proportion indicated by the velocities established.

Preheating Air and Waste Heat Boilers

I believe it is well established that in preheating the air and gas for combustion, the actual gain to the furnace is not to be measured by the fuel equivalent represented by this preheat. In general, it far exceeds that amount and results in reduced fuel per unit of product and increased product per unit of time.

The flame, before producing its final results, must have reached a certain intensity of temperature. If the possibilities of the flame have been almost exhausted in reaching and maintaining that temperature, the operation lags and the expenditure of fuel becomes serious. On the other hand, if the possibilities of the flame are in excess of the requirements of the operation, this excess energy serves to speed up the operation and reduce the fuel expended per unit of output. This excess is the useful work of the flame and is in proportion to the difference between the actual temperature required and the temperature possible, the former temperature being established by the operating requirements and the latter by the combustion conditions. If the combustion conditions are so bad that only a small portion of the flame energy is available for the useful work, then a small improvement in those conditions may show a marked gain in this useful work, as all other losses have been supplied.

To effect maximum economies, we must establish such conditions within the furnace as will increase to a maximum the useful work of the flame and the rate of generation. Therefore, any combustion improvement having for its purpose increasing the flame temperature, must react economically upon the furnace performance.

Gases brought down to 1,600 deg. F. or lower by means of regenerators or recuperators are not too hot for the successful and continued operation of metallic recuperators. This fact again reduces the field of operation for the boiler by at least sharing it with the recuperators, which feature has been advocated by at least one concern, and not without some commendation.

Upon the supposition that the waste gases leave the furnace at 2,800 deg. F. and enter the regenerators through the customary downtakes; that they leave the regenerators at 1,700 deg. F.; that such portion of the waste gases as is required to heat the air for combustion is passed through a metallic recuperator and the remainder through a waste heat boiler, and that these gases enter the base of the stack at 500 deg. F., calculations indicate that with 20 per cent less regenerator capacity and 25 per cent less waste heat boiler capacity, plus the added recuperators, there would be effected a saving around 13 per cent in fuel per ton of steel plus an undetermined increase in furnace capacity, as compared with present furnace practice plus a waste heat boiler.

Then there is also to be considered the elimination of the gas checkers (in the case of producer gas) and an increase in the air checker chamber to a point where the temperature of the waste gases is reduced to 500 deg. F. or less. This will eliminate the possibility of using natural draft, and the air will have to be forced into and the waste gases drawn out of the checker chamber with fans. A further modification would be to divert, from some point in the air checker chamber, where the temperature is about 1,600 deg. F., a portion of the waste gases to a waste heat boiler of sufficient capacity to generate steam required for gas producers or other furnace auxiliaries.

Heat Losses

The open-hearth and heating furnaces as we have them today are not likely to soon undergo any radical changes in the fundamentals of their design. This being true, our problem is as much one of careful preservation of the good features as of radical change or invention.

Therefore, any suggestion for the prevention of heat losses anywhere in the installation from the source of heat energy to the stack should be viewed with interest, and the benefit of a doubt placed upon the side of heat conservation rather than upon the side of "good enough."

Purpose of Tests

Tests made upon waste heat boilers should be accepted and their results analyzed with the following considerations in mind:

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First—Performance of the boiler.

Second—Justification for its installation.

Testing for performance may be accomplished with complete satisfaction to the purchaser as well as to the designer by observations of several hours' duration, or as in the case of open-hearth furnaces during the time of a single heat. By such a test, the possibilities of the installation may be fully demonstrated.

Beyond this, the designers and builders cannot be held responsible, nor are they interested, except in so far as it assists in developing the field for the disposal of their product.

Up to this point, the boiler may be a success, but there still remains the justification for its installation.

From this point on, the boiler performances will be affected by variations in plant operations, interplant co-operation, trade demands and many small and provoking interruptions, all of which when properly considered may serve to either justify or condemn the expenditure.

Therefore, ordinary test figures are too apt to present mostly the possibilities of the installation, while the actual justification must be determined from the cost sheets of the plant, or from such prolonged periods of observation as will include sufficient irregularities and unexpected features to reflect correctly the actual conditions under which the boiler must justify its existence.

General Considerations

It is no doubt apparent that the foregoing presentation has been based entirely upon conditions existing in the manufacture of steel and that the conclusions formed apply more particularly to that industry.

Periodically, in the past, we have been confronted with the reclamation problem in some form or another, and generally the first conclusion has been to install something directly for reclamation; whereas waste reduction by improving the primary unit becomes a consideration only after repeated failures at reclamation. Some years ago, smoke consumers engaged the attention of many engineers and for a while seemed destined to reimburse the manager for the losses from poor combustion. Also, at one time, instead of trying to reduce the coke consumption per ton of pig iron, it was considered wise by some to increase this amount in order that more blast furnace gas would be available, and thus return a profit in excess of the expenditure. A third recollection is the low-pressure steam turbine, which, in conjunction with wasteful high-pressure reciprocating engines, was to be the true remedy for steam power wastes. Within a comparatively short time, all of these proposals have been advocated, applied and displaced by a reversion to the primary unit and the development of its possibilities.

These incidents indicate that increased economies most likely can be obtained by improving the primary unit, and when that fails, the primary unit itself must be displaced.

Extraordinary savings effected by a waste heat boiler might well be accepted as a warning to improve the combustion or furnace design rather than as a cause for rejoicing.

Generally speaking, when the steam generated by the recovery of heat is returned to or utilized by the primary unit, the waste heat boiler can possibly be advantageously and economically used, but when the steam so generated is not thus required, or when it is in excess of those demands, study of the returns from such installation costs is very apt to decide against such recovery.

There are instances, however, where the completed cycle of operations is compelled to discharge the finished product at a temperature far in excess of that desired or permissible for handling or utilizing that product.

This is the case with rolled materials just after leaving the rolls; slags, etc., after entering the ladles; coke as it is discharged from the ovens.

Heat reclamation under such conditions may truly be most inviting, because no recovery method whatever will return this energy to the primary unit or process.

Conclusions

1—While the generation of steam is in general a very feasible way of recovering waste heat energy, an installation for the purpose is apt to be one of the most expensive and the ultimate results no better than those possible with a less costly scheme.

2—Metallic recuperators are now capable of receiving the hot burned gases as high as 1,600 deg. F., or higher, which fact very seriously affects the justification for waste heat boilers, and when used in connection with regenerators, may exclude the necessity for installing a steam generating unit.

3—Increased knowledge and more careful observation of the laws of heat generation and absorption apparently lead to the elimination of divided or multiple systems of heat utilization in order to effect maximum economy.

4—Complete utilization of heat by the primary heating unit promotes economies in excess of those represented by the performance of the boiler.

5—Apparently the field wherein the waste heat boiler can make the best showing is the one wherein the reclaimed energy is not required directly by the process from which it came.

The Telephotograph Carries Market Tips

The feasibility of simultaneous publication of important news on both coasts of the United States by use of telephotographs is being demonstrated in striking fashion by the Brookmire Economic Service of New York. This company has just inaugurated the practice of sending part of its weekly market bulletin from New York to San Francisco by telephotograph. The material, transmitted across the continent in seven minutes, is printed each Saturday and distributed to Western Coast clients from the San Francisco office at the same time that it is sent out from New York.

This illustrates a comparatively new adaptation of the telephotograph. When this service was first offered to the public it was used primarily for the transmission of news photographs—pictures of disasters, transatlantic fliers and events of national importance.

The device has now found a newer and much wider field of commercial service as a means of rapidly transmitting information "in bulk." Instead of reproducing only pictures of persons, objects or events, it now reproduces facsimiles of long letters, statements and important documents.

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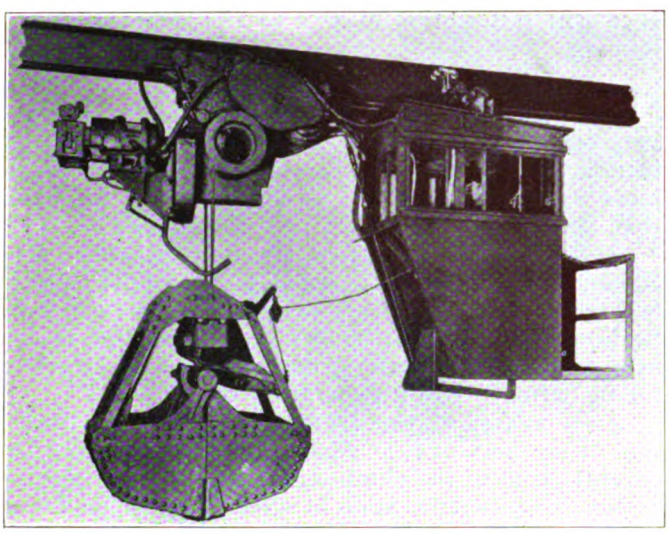
WITH THE EQUIPMENT MANUFACTURERS

New Monorail Trolley

The accompanying illustration shows a monorail trolley brought out by Edgar E. Brosius, Inc., Sharpsburg, Pa., a number of which have been in service in the steel plants for the past three or four years. It is especially rugged for severe, continuous work, being built entirely of steel, and the hoist is equipped



with a simple worm gear drive. It is furnished with a hook block for handling the Brosius single hook bucket, or the bucket can be reeved direct to the drum, as shown in the illustration. The worm drive requires only a simple magnetic brake on the hoist motor for holding the load, in conjunction with dynamic braking control. The hoist is equipped with Timken roller bearings, while the design of the trolley is very simple and rugged and the trolley drive is of the spur gear type. Bulletin Nos. 28 and 41 describing the hoist will be sent on request.

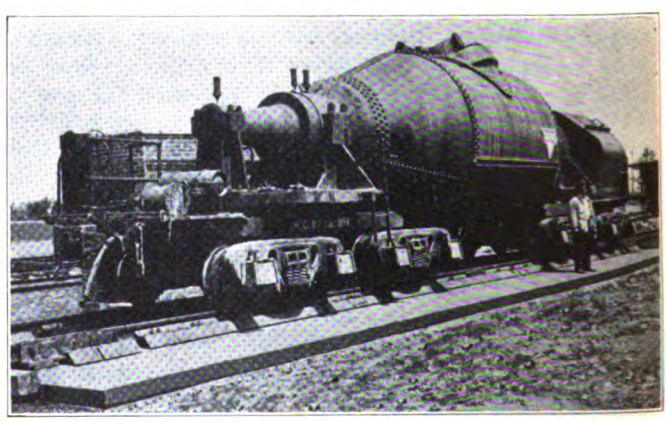
Scale for Weighing Molten Metal in Transit

In building the plant of the Hamilton Coke & Iron Company, at Hamilton, Ohio, which was handled by the Koppers Construction Company, the problem of weighing cars of molten metal was solved by the installation of a two section type "S" Fairbanks suspension bearing knife edge track scale. This scale has a capacity of 250 tons for each section and a beam capacity of 800,000 lbs.

The Pugh type of hot metal cars which are used to transport the molten pig iron a distance of 12 miles to the open-hearth plant have a capacity of 150 tons each and represent a total load of 343 tons. This load is carried on a wheel base of 45 ft. 6 in. with a maximum axle load of 85,600 lbs. The car is carried on two 8-wheel trucks or 16 wheels in all. This concentration of the load required a scale of unusually heavy construction. Standard gauge track is used and the scale with a weigh rail 56 ft. long is built in two sections. The rail stands are supported with heavy steel cross ties and special housings are used around each of the rail stands. The deck is built of ⅜ in. steel plate covered with fire brick and a special type of storm guard is used so as to protect the openings made by the rail stand housings. There are four primary or main levers transmitting the load to two longitudinal extension levers which in turn transmit the load to a transverse extension lever which connects to the weigh beam. This beam is type registering so that the weight is printed on the scale ticket and there are double slides so that weights can be taken to an accuracy of 20 lbs. if desired. With test car loading of 220,000 lbs. the scale showed an error of only 20 lbs., which is too small to warrant any effort to remove.

The open hearth plant at Middletown, which is supplied by the Hamilton Coke & Iron Company plant had formerly operated on 100 per cent cold pig iron and is not equipped with a mixer. The Pugh cars will furnish the open hearth with a supply of hot metal and eliminates the installation cost of a regular mixer. In addition to providing transportation for hot metal these cars also furnish hot metal storage capacity. Since iron from only one blast furnace is transported in a car these cars do not function as mixers.

It is said that a larger tonnage can be handled in a single trip with this single unit than with any other type of ladle. The formation of ladle scrap is also eliminated and if desired considerable cold scrap can be melted. From 4 to 5 per cent in weight of metal can be added without a direct fuel charge.



Although the scale was installed primarily for determining the weight of pig iron shipped out in the form of hot metal, it will also be used for general weighing of inbound and outbound commodities.

Link-Belt Announces a New Two-Yard Shovel

Indicative of the trend toward the more powerful, greater capacity machine is the announcement by Link-Belt Company, of Chicago, Indianapolis and Philadelphia, of the addition of a full 2-yard capacity machine to their line of crawler cranes, shovels and draglines. Heretofore the largest capacity machine built by this company was a 1½ yard unit.

(Continued on page 1087)

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Manufacture of Coke at Massillon

In This Description of the General Layout and Operation of a Strictly Modern By-product Coke Plant the Transit of Materials Is Clearly Outlined

By C. R. LOHREY*

THE Massillon Coke Plant of the Central Alloy Steel Corporation started operation on April 21, 1927. The completion of this plant placed within the company's control the final link in the chain of processes from the raw materials, coal and iron ore, to the finished steel products. Prior to the above date the supply of coke for the blast furnace was obtained from various sources and the lack of uniformity in this material did not make for the best results in the operation of the furnace. The coke plant was projected and built primarily for the purpose of supplying Betty furnace with a sufficient quantity of coke and of such a quality as is required to produce the grade of pig iron used in the manufacture of high grade alloy steels such as are produced in this plant. A secondary consideration, of course, was the supply of coke-oven gas and tar made available as an economic fuel for use in the open hearth and rolling mill departments.

General Features

The site of the coke plant is adjacent and to the south of the blast furnace, with ample room for future extention to be made toward the south. Future blast furnace additions will be made to the north of the present furnace. This site permits of a very short haul for coke to the furnace. The land is made up of gravel to a great depth and affords a good foundation for the heavy oven brick work which, of course, must not settle in the least after construction is complete; a very slight change in elevation or alignment may produce cracks and leaks that would be ruinous to the entire battery.

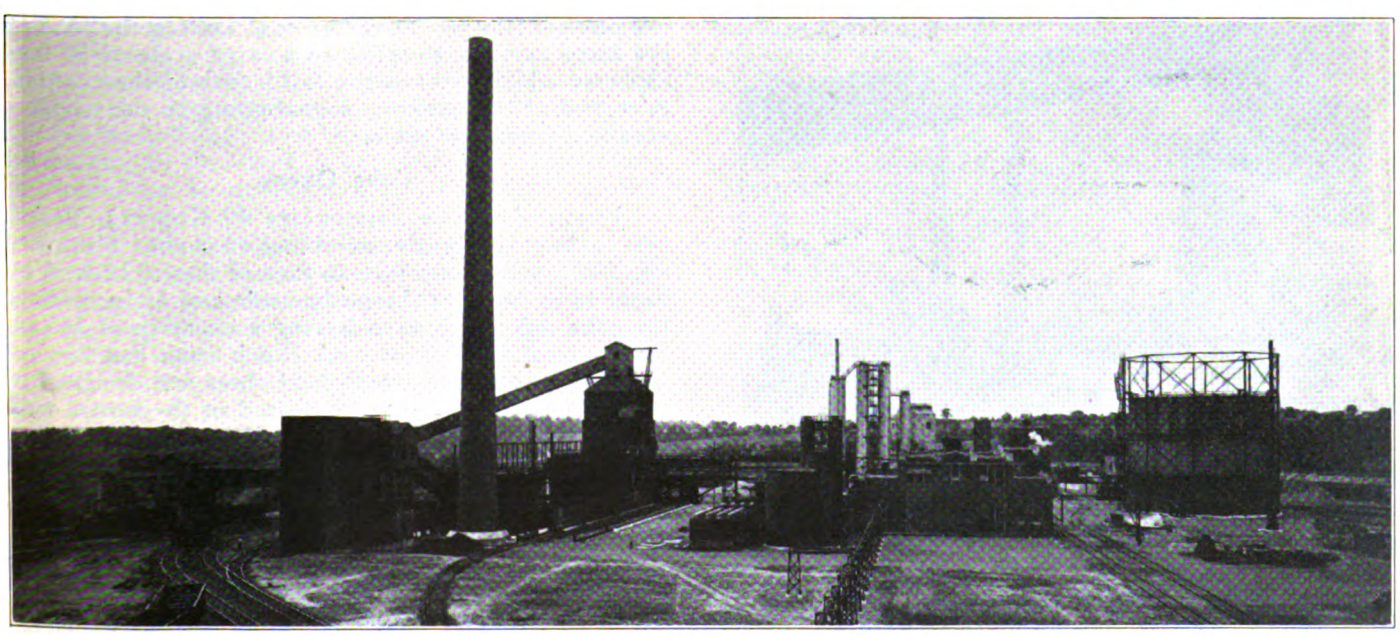
*General foreman, Massillon Coke Plant of the Central Alloy Steel Corporation.

The architecture of the buildings is uniform throughout the coke plant, blast furnace and power house division. Outside walls are faced with red rough-faced brick, inside walls with the light yellow salt glazed brick, and floors are finished either with ceramic tile or smoothly finished concrete. Floors in the sulphate handling and storage rooms are covered with 1½ in. of asphalt. Steel window sash with reinforced wire glass panes are used throughout, with clear glass up to the line of vision only. The roofs on the by-product plant and benzol plant buildings are four-ply composition on gypsum slabs. The gypsum absorbs the condensation and prevents dropping on floors and apparatus.

Raw water is supplied from the company's deep wells and is delivered at an almost constant temperature of 11 deg. C. throughout the entire year. The temporary hardness being quite high in the raw water, it is necessary to use treated water in all of the enclosed cooling devices in the plant. This is supplied by the water-softening plant located at the boiler house. Steam at 275 lbs. gauge pressure, 150 deg. F. superheat, d.c. and a.c. are all supplied by a very modern boiler house and power plant located adjacent to the blast furnace.

A more or less detailed description of the plant will be obtained by following the process from the receipt of the coal at the coke plant to the finished coke and by-products.

It has been proven quite conclusively that the degree of pulverization of the coal going into the ovens is a very important factor, not only in the ease of operation of the ovens, but also in the quality of the coke produced. Should it become necessary for this



A view of the plant from the power house, looking south.

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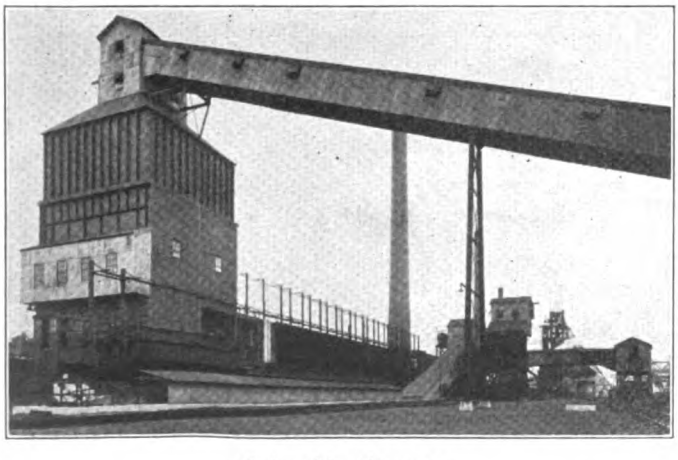
plant to change the source of the coal supply, it would very probably be necessary to change the degree of pulverization of one or of all the coals which go to make up the final mixture. This would be necessary in order to assure the blast furnace that we deliver to them a coke of constant quality at all times. The design of the coal handling is such as to make possible the accurate control of the degree of pulverization of the coals over a wide range.

Coal Handling

Coal is delivered to the coal handling yard in bottom dump cars by the railroad switching crew. A 125-hp. electric locomotive moves the cars to the unloading building where the coal is dropped into twin track hoppers. A duplex shaker feeder driven by a 15-hp. motor through an enclosed gear reduction, feeds the coal into a 36-in. conveyor belt (C_1) which carries it to the top of the breaker building and delivers it into a 12 ft. by 17 ft. Bradford breaker. This breaker is arranged with 1½ in. round openings and breaks up the coal to pass through these holes. The refuse wood, pieces of slate, iron, etc., are discharged at the end of the breaker through a chute into an open top car. Coal through the holes drops into a small gathering hopper from which it flows into the hammer mill located directly beneath the breaker. At the bottom of this gathering hopper is a chute and butterfly valve arranged so that the hammer mill may be bypassed if so desired. The top casing of the Bradford breaker serves as the roof for the building.

The hammer mill is driven by a 300-hp. synchronous motor located in a dust-proof room adjacent to the mill and is directly connected to this motor through a flexible coupling. The motor turns on roller bearings. A retarding feeder regulates the flow of coal to the mill.

A 30-in. conveyor (C_2) carries the pulverized coal from the hammer mill to the top of the mixer building and discharges it through an adjustable chute into any one of four 200-ton capacity mixer bins. The chute is operated by a drum and wire rope from the mixer floor located beneath these bins. An automatic device



Coke side of ovens.

in the top of each bin indicates to the operator on the mixer floor, by means of an electric klaxon, when the bin is full.

These bins are of reinforced concrete construction with sloping bottoms, which are lined with hard vitrified brick. Under each bin is a short 36-in. conveyor belt, called a mixer belt (C_3, C_4, C_5, C_6,) which delivers out of the bin onto a short receiver belt (C_7) running at right angles to the mixer belts. Regulating gates at the bottom of each bin regulate the height of the coal stream from each bin, which of course regulates the proportion of each kind of coal used to make up the coking mixture. An electric cutout device is arranged so that if for any reason the stream of coal from any one bin ceases, the four mixer belts are automatically stopped. This insures at all times a coal mixture of constant proportion volumetrically; and by determining the weight per unit volume of each coal daily, a constant proportion by weight is maintained.

Running at right angles to the receiver belt (C_7) is a 30-in. belt (C_8) which carries the coal mixture part way up to the oven bin, and delivers its load onto a second 30-in. belt (C_9) which travels at right angles to (C_8) and completes the journey of the coal mixture to the 1200 ton capacity oven storage bin. At the foot of (C_8) conveyor, extending above and across the belt, is a water sprinkler used to make additions of water whenever necessary to maintain any desired moisture content. The chute at the head of (C_8) conveyor is so arranged that it can be made to discharge onto a second (C_9) belt which would discharge into the oven bin that would be provided for additional batteries of ovens. At the head of (C_9) belt, in the chute to the oven storage bins, there are mixer paddles installed; these are driven from the head shaft of this conveyor through sprockets and chains and spur gear.

The capacity of the coal handling equipment is 150 tons per hour. By speeding up belts and installing an additional car dumper, Bradford breaker and hammer mill, the capacity up to the mixer bins may be increased to 300 tons per hour.

The 1200-ton oven bin is built of steel plates with bottom cones lined with vitrified brick. It is built in two bays with two rows, five hoppers each, in each bay. Coal may be drawn from any one of the four rows through five manually operated cut-off gates, operated from the larry scale platform, into a larry car. This car is built with five cone shaped hoppers, and is used to convey the coal from the storage bin and discharge it into the ovens through the five charging holes in the top of each oven. During the loading the larry car is supported on a larry scale of 50 tons capacity which extends the full length of the coal bin. A record of the amount of coal going to the ovens is obtained from this scale.

Coke Ovens

Arranged in one battery are 49 Koppers, Becker type, cross-regenerative combination ovens. The ovens are 40 ft. 8 in. long, face to face of doors, 12 ft. 6 in. high, 13 in. wide at the pusher side and 15 in. wide at the coke side, each oven having a capacity of 546 cu. ft. or about 14 tons of coal. Each oven has two regenerators, and the waste heat flues are designed in size that the ovens may be heated in the future with blast-furnace gas; the flues will accommodate five additional ovens heating with coke oven or producer gas. There are 27 rectangular heating flues between each oven, 13 on the pusher side and 14 on the coke side, and over every other oven chamber are six cross-over flues connecting the horizontal flues on either side of the oven.

The coke-oven gas for heating the ovens is delivered from a 10,000 cu. ft. fuel-gas holder, operating

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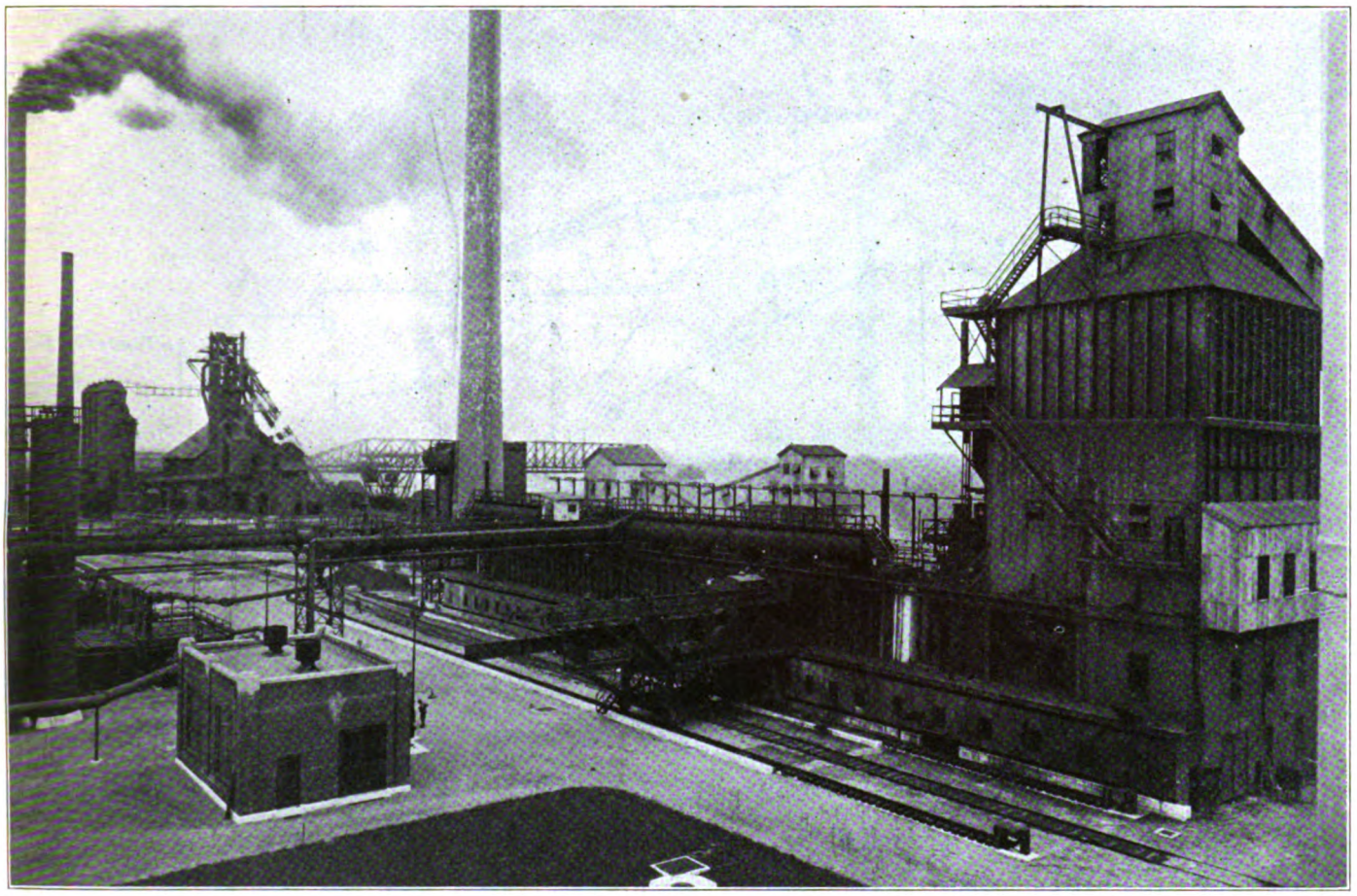

The pusher side of the battery.

at 10 in. water pressure, through a fuel-gas heater and a Venturi meter into the mains on either side of the battery. The heater and meter are each provided with a by-pass to allow for cleaning. Between the regulating cocks and the gas guns flexible metal hose connections are used to prevent strains caused by the movement of the gas main during temperature changes. The gas guns are provided with decarbonizing caps for admitting air to burn out any carbon deposits formed in the gas ports and nozzles while the gas is burning. The waste heat flues are connected to a radial brick stack, 11 ft. inside diameter and 250 ft. high; this size stack will accommodate blast-furnace gas underfiring. The butterfly valve in the main flue leading to the stack is actuated by a Shallcross draft regulator to maintain a constant draft in the flues.

A brick enclosed room at the stock end of the battery at bench level houses the reversing machine and battery instruments and gauges. The gears on the reversing machine are enclosed in an oiltight casing and operate in oil. A Dake motor, which operates with either steam or air, operates the reversing machine in case of failure of the regular electric motor provided for this purpose. Instead of the usual counterweighting of the reversing cable, a continuous cable, arranged with a spring and turn buckle adjustment, has proven very satisfactory, thus eliminating the use of couterweights.

Drawing the Coke

On completion of the coking period the coke is pushed from the oven by the pusher machine into the quenching car which hauls it to the quenching station located at the north end of the battery. Here it receives a water or a still waste quench depending whether or not the ammonia still is operating, and is delivered onto the wharf.

The pusher machine is the usual Kopper machine with leveller bar for levelling the coal in the top of the oven during the charging period, and the door extractor for removing the pusher side doors. A square ram and levelling bar are kept at the ram changing station, located on the north end of the battery, to provide for emergencies. On the pusher ram a decarbonizing device was recently installed, which blows a strong current of air toward the roof of the oven chamber as the oven is being pushed. This is designed to remove carbon deposits which accumulate at the top of the ovens. Such deposits interfere with the yield of by-products by acting in a somewhat catalytic manner as an aid to cracking processes which decompose desirable compounds into undesirable ones.

There is one clay carrier on the pusher side and two (one as a spare) on the coke side. The elevator on each carrier is operated by a motor and contains one compartment for old clay and one for new. The door difting machine on the coke side is of heavy construction to handle the heavy doors; this machine is used also to propel and spot the coke guide in position ready for pushing.

The quenching station is the recirculating type. The quenching liquid flows from a 12,000-gal. capacity tank, located 50 ft. above the quenching track level, into two sprinkler pipes located above the quenching car so that an even distribution of liquid is obtained

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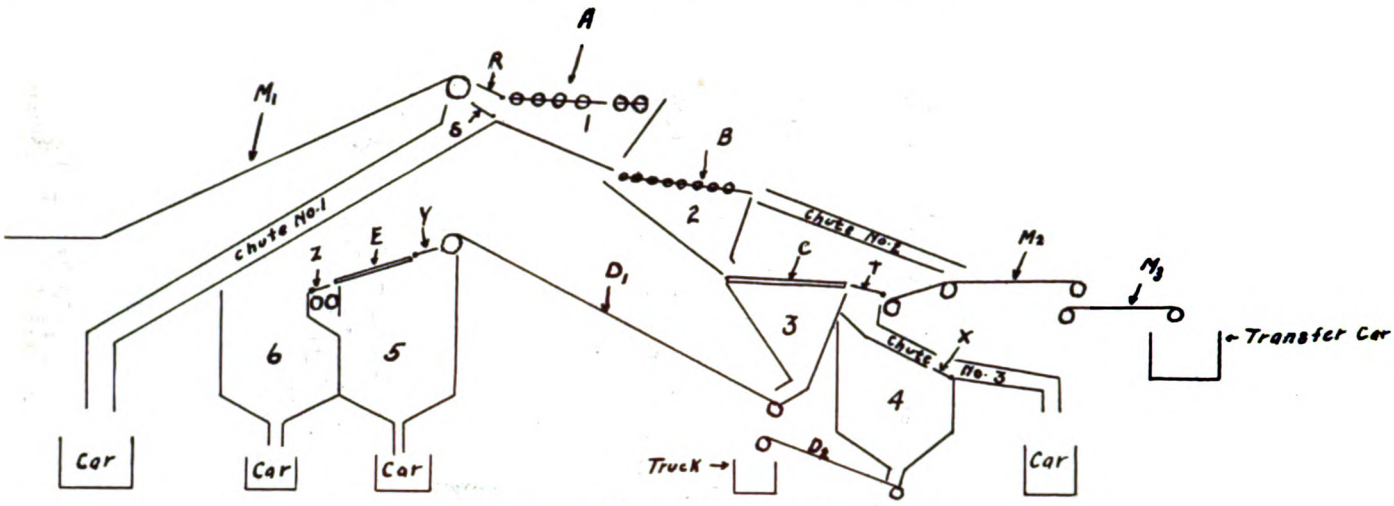

FIG. 1—Line diagram of coke screening station.

which quickly and uniformly quenches the coke. The liquid not evaporated flows from the car into a reinforced concrete settling sump, which collects any small coke washed away during quenching, then under baffles and through a screen into a hot well, from which it is pumped into the tank by one of two centrifugal pumps. Each pump has a capacity of 30,000 gals. per hour at 175 deg. F. against a head of 80 ft. and suction head of 3 ft. The pumps are motor driven and are automatically started and stopped by a device operated by a float in the tank.

Coke Handling

The coke wharf is 120 ft. long between walls and will hold three ovens of coke. The inclined surface is lined with 1 in. cast iron wearing plates. Coke is fed from the wharf through 3-ft. gates operated from a platform extending along the entire length of the wharf. Any hot coke is spot quenched by the operator before dropping onto the wharf belt which conveys the coke to the screening station.

The screening station is shown diagrammatically in Fig. 1. The system is quite flexible in that it is possible to produce a variety of coke sizes by using the several combinations of screens available. The capacity of the system is 75 tons per hour with provisions for increasing this to 100 tons per hour. The coke from the wharf is carried on a 36-in. conveyor belt (M_1) up to a combined scalping grizzly and two-roll crusher (A). The oversize from the grizzly passes through the adjustable roll crusher and is crushed to a maximum size of 3¼ in. The undersize from the scalping grizzly and the coke through the crusher is delivered through the collecting bin (1) to the eight-shaft furnace grizzly (B). An automatic electric cut-off is attached to the lower shaft of the grizzly so that if this shaft ceases to revolve the entire system behind the grizzly will stop. At the head of (M_1) belt are two chute valves (R) and (S). With (R) open the scalping grizzly is by-passed and the coke goes directly to the furnace grizzly; if both (R) and (S) are open the entire screening station is by-passed and run-of-oven coke is delivered into cars through chute No. 1.

The coke over the furnace grizzly flows through a brick lined chute (No. 2) onto the 36-in conveyor belt (M_2) which delivers onto a 36-in. boom conveyor (M_3) into the transfer car for transportation to the blast furnace bins, or into cars for the trade. The undersize from the furnace grizzly is delivered through collecting hopper (2) onto a 4 ft. by 6 ft. high speed shaking screen (C). The coke over this screen passes onto conveyor belt (M_2) and goes along with the oversize from the furnace grizzly when the valve (T) is in the closed position as indicated in the Fig. 1. By opening this valve (T) the shaking screen oversize passes through chute No. 3 into cars for shipment to trade; by opening the chute valve (X) this coke is diverted into the bin (4) from which it is loaded by means of the conveyor belt (D_2) into trucks for local delivery.

A small collecting bin (3), into which the undersize from the shaking screen falls, delivers onto the 18-in. conveyor belt (D_1). At the head of (D_1) belt the chute valve (Y) delivers the coke either into bin (5) directly or onto the high speed vibrating screen (E). Another valve (Z), when open, diverts the oversize from the vibrating screen through a two-roll crusher into bin (5) along with the undersize from the screen. With the valve (Z) closed the oversize from the screen is delivered into bin (6) as a separate product. Both bins (5 and 6) deliver into cars through hand operated gates controlled at yard level. The sizes of all screens may be changed to produce products of any desired screen test.

Weighing the Coke to the Blast Furnace

The bin of the transfer car used to deliver coke to the blast furnace bins is mounted on the car trucks by a beam scale which gives a record of the weight of each load going to the furnace. The car is electrically operated and is controlled from either end. The coke is discharged into the furnace bins through side opening gates operated by air cylinders much the same as on the quenching car.

All conveyor galleries, junction houses, and buildings in both the coal handling and the coke handling, with the exception of the concrete mixer building in the coal handling, are made of structural steel covered with corrugated galvanized roofing and siding. Floors along both sides of the conveyor belts are 2-in. reinforced precast concrete slabs provided with cleats at regular intervals to prevent slipping. All motors driving conveyor belts are equipped with solenoid hold-back brakes through Kopper drives. The troughing idlers and return idlers are mounted on roller bearings and are equipped with "Dot" fittings for grease lubrication. The coal system and the coke systems are electrically interlocked to prevent a pile-up on any head

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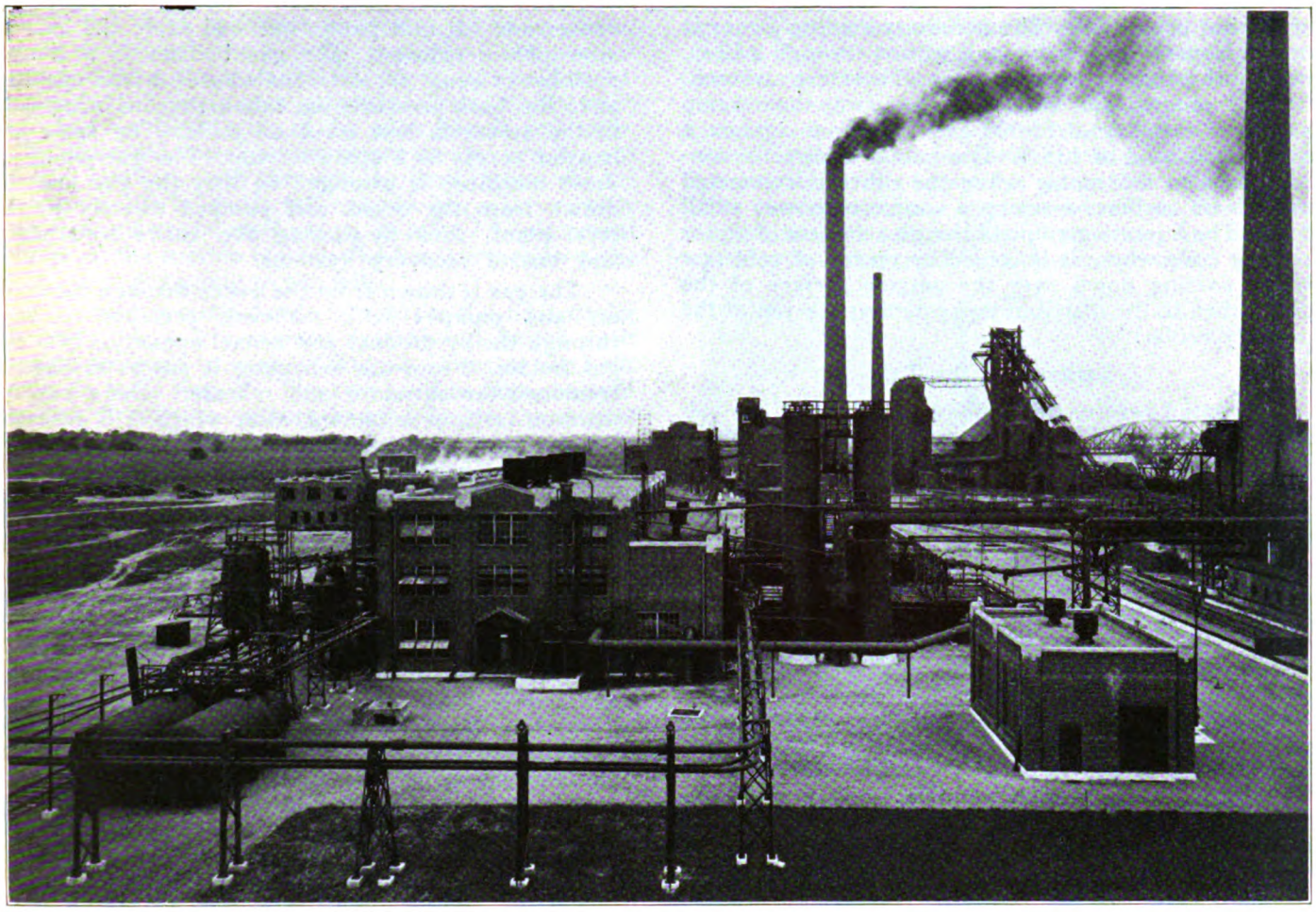

View of by-product building from benzol plant.

belt, and the entire system may be stopped simultaneously from push button stations located at several easily accessible points. A special controller was designed that would allow the interlocking system in the coke handling to function with any combination of apparatus in operation.

Taking Off Distillation Products

The products of distillation which are driven off during the coking process pass out of the oven through a "Ramtite" ascension pipe, cast iron goose neck and damper box into a 63-in. collecting main. Liquor sprays in the saucer type dampers, and in the collecting main cool the gases to approximately 85 deg. C., and condense a great portion of the tar and moisture out of the gas. At each end of the collecting main is a bleeder with a liquor sealed relief valve for emergencies. The main slopes from both ends toward the center where a 36-in. off-take main is connected to convey the gases to the suction main to the primary coolers. The tar and moisture which condenses is washed by the flushing liquor out of the collecting main through a combination pitch trap and butterfly valve into the downcomer at the suction main and flows into the hot drain tank through a 14 in. pipe, while the gases pass on through the suction main to the primary coolers.

An extremely important feature in good oven operation is the maintenance of a uniform back pressure in the collecting main and ovens. A pressure regulator operating the butterfly valve in the off-take main maintains this pressure constant within less than one mm. water pressure variation. A similar governor operates the throttle valve on the exhauster turbine to maintain a quite uniform suction on the suction main; this governor of course co-operates with the off-take regulator to maintain this close regulation.

By-Product Plant

The by-product building is parallel to and some 200 ft. west of the ovens. The main building is 118 ft. long by 54 ft. wide by 32 ft. high to the bottom chord of the roof trusses; the crane runway is supported on the columns. The by-product apparatus, sulphate handling and sulphate storage are contained in the main building. A leanto along the entire east side of the building houses the surplus gas meter, air compressor, vacuum pump, liquor flushing and liquor cooling pumps, hot drain transfer pumps and tar loading pump. The north end of the leanto is partitioned off as a service room for the operators. A leanto on the west side provides space for the ammonia still and lime handling equipment.

The two primary coolers are the direct contact type, 60 ft. high by 9 ft. dia. Gas is drawn up through the cooler and comes in intimate contact with the cooling liquor flowing down over wooden hurdles from the splash spray distributing system on top. The bottom of each cooler acts as a tank for the separation of tar and liquor; the tar, along with the excess liquor overflowing from the top of the tank section, flows into an open catch box into the settling compartment

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of the hot drain tank. The necessary cooling liquor is drawn from the top of the tank section through a 12-in. line by the cooling liquor pumps. These are two centrifugal pumps, one serving as a spare, each pump having a capacity of 55,000 gals. per hour against a differential head of 135 ft. One pump is directly connected to an a.c. motor while the other is connected to a steam turbine, assuring a source of power at all times. The liquor is pumped through a system of liquor cooling coils where it is cooled by means of cold raw water passing down over the outside surface of the pipes, then to the distributing system at the top of the primary cooler.

Removal of the Tar

As stated before, the liquor flushing from the collecting main along with the tar and liquor condensed in this main flow to the screening section of the hot drain tank. This tank is approximately 57 ft. long by 26 ft. wide by 9 ft. 7 in high overall. The returned flushing enters one of two screening compartments, passes through a wire mesh screen to one of two settling compartments where the tar settles from the liquor by gravity and flows out through the adjustable overflow pipe into the tar compartment. The tar is pumped from this compartment to a separating tank of 50,000 gals. capacity, where any excess moisture separates. The dry tar flows through an adjustable overflow into a tar storage tank having a capacity of 180,000 gals. A triplex plunger pump connected to an a.c. motor pumps the tar from the storage tank into tank cars for delivery to the open hearth department as a fuel. The liquor overflows through a weir at the end of the settling compartment into the flushing compartment, and the excess liquor, equivalent to the amount produced, overflows through another weir in the top of the flushing compartment into the ammonia liquor compartment from which it is pumped to the 85,000-gal. liquor storage tank. Liquor for flushing is pumped from the bottom of the flushing compartment to the collecting main by one of two centrifugal pumps, each with a capacity of 55,000 gals. per hour against a differential head of 45 lbs. gauge pressure. One pump is motor driven while the other is driven by a steam turbine.

Four motor driven centrifugal pumps are connected to the hot drain tank so that each pumping operation may be performed by one of two pumps. Each of these transfer pumps has a capacity of 6,000 gals. per hour against a differential head of 75 ft.

All the tar and liquor lines are provided with drain connections to a condensate drain tank located below yard level. This tank also receives the overflow from the tar and liquor tanks, the drain from the tar extractors, reheaters, exhausters, and the underground drips in the gas line. A submerged centrifugal pump operated by a motor, discharges the tar and liquor into the hot drain tank. The motor is controlled by a float in the tank.

The by-product apparatus is built in pairs, one of each with sufficient capacity to handle the gas and one as a spare. The exhausters are the three-stage turbo type, each with a capacity of 14,900 cu. ft. per minute at 110 deg. F., saturated, and minus 10 in. water column suction, and a discharge pressure of 2½ lbs. normal or 3½ lbs. maximum. They are directly connected to steam turbines equipped with regulators and overspeed governors. The turbines operate at 28 in. vacuum, which is obtained through a barometric condenser and vacuum pump, but will carry the load at atmospheric exhaust. The gas booster is a similar machine of equal capacity but whose turbine operates at 15 lbs. back pressure, the exhaust steam being used in the ammonia and wash oil stills. The spare exhauster serves as a spare booster. The gas piping at these machines is arranged so that the gas may be drawn from the ovens and pumped directly to the steel plant, thus by-passing the entire by-product and benzol recovery systems.

The gas is drawn from the ovens through the coolers and pumped with sufficient pressure to pass through the by-product and benzol apparatus into the gas holder. From the exhauster it passes through a combined tar extractor and reheater, where any remaining tar is precipitated, after which it is reheated by coming in contact with steam heated radiator sections in the reheater. The five circular tar extractor bells are in the top section above the reheater. Passing outside the building the gas enters a 12 ft. round saturator where the ammonia is taken out by bubbling through a sulphuric acid solution forming ammonium sulphate crystals. These crystals are collected on a lead lined drain table inside the building. At each drain table there is one centrifugal salt drier which is driven by a two-speed motor located beneath the drier and directly connected to it through a flexible coupling. After washing and drying, the ammonium sulphate is cut from the drier basket by means of mechanical unloader, and falls through a chute onto a 24-in. conveyor belt which delivers it into a pit in the sulphate room. An electric crane transfers the salt to the storage room. This crane also loads into the bagging hoper from which a conveyor carries the salt into a car, or it loads a hopper which feeds the sulphate drying kiln when making Arcadian sulphate.

The milk of lime for the ammonia still is mixed in a tank provided with a motor driven agitator. Lime is fed from a storage hopper through a variable speed screw conveyor to the mixing tank, while service water runs into the tank over a V notch weir. These two features make it possible to easily control the volumes and the concentration of milk desired. A motor driven centrifugal pump delivers the milk of lime to the flow box above the still from which it flows to the still by gravity. The storage hopper is filled each day from the lime storage room through a crusher and bucket conveyor. The capacity of the hopper is ample for 24 hours supply. The ammonia liquor is pumped from the storage tank to the 500-gal. constant level tank over the still and flows through a Venturi meter to the still. The ammonia vapors pass out the top of the still through a dephlegmator, where a portion of the moisture is precipitated, and are mixed with the gas at the suction main inlet to the primary coolers. A blanked connection is provided at the outlet connection of the reheaters for the purpose of admitting the ammonia vapors at that point if so desired.

Benzol Plant

The gas travels from the by-product apparatus through an underground main to the benzol plant where it passes through the final cooler, two wash oil scrubbers, the total gas Venturi meter, and to the fuel gas holder. By means of a set of automatic valves operated by this holder, the gas stream is divided, part going to the ovens for heating, and the surplus passing through the liquid purification tower where the major portion of the hydrogen sulphide is removed.

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After this final purifying treatment which makes it more desirable for use in the steel plant, the surplus gas goes to a three-lift 500,000 cu. ft. gas holder, operating at 5 in. water pressure, from which it is pumped by the booster to the open hearth and mills. The automatic valve arrangement on the surplus gas holder sends the gas through the bleeder into the air whenever the holder is full and the gas make exceeds the demand at the steel plant. A rotary displacement meter on the suction main to the booster measures the volume of gas going to the mills.

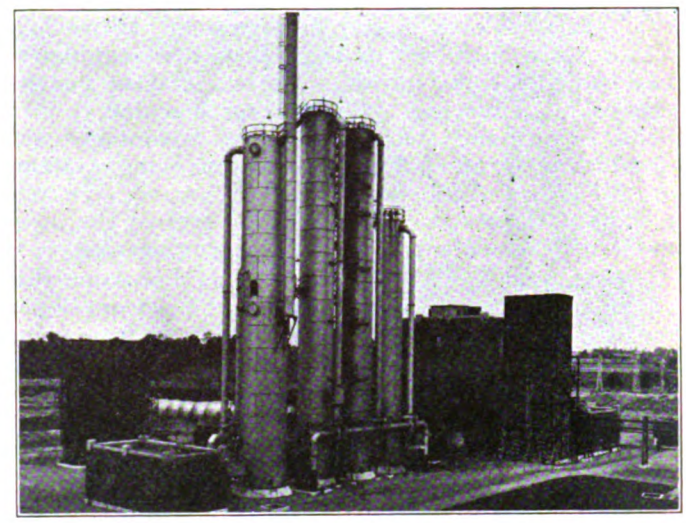
A water cooling tower is used in the final cooler system; this is a combined natural and forced draft tower, designed to cool 40,000 gals. of water per hour from 95 to 75 deg. F. The two built-in fans are connected directly to motors located inside the benzol pump room. Three centrifugal motor driven pumps, 40,000 gals. per hour capacity, recirculate the water through this system; one delivers to the top of the final cooler, one to the top of the cooling tower and one serves as a spare for either operation. A naphthalene sump, with a working volume of about 1,040 cu. ft. allows for the separation of naphthalene from the water.

The pump room is a leanto at the north end of the benzol building, and is separated from the still room by a wall with no openings between the two rooms, thus confining the benzol vapors to the still room alone. The pump room houses, along with the final cooler pumps, two motor driven centrifugal soda solution pumps for the circulation of the soda solution through the gas purifier, and five centrifugal pumps, motor driven, for the wash oil circulation. These five pumps, each having a capacity of 10,000 gals. per hour against a head of 135 ft., circulates the oil through the two 10 by 100 ft. scrubbers and through the debenzolizing apparatus and coolers; one pump is a spare that may be substituted for any one of the other four.

The oil enriched with benzol and its homologues flows from the second scrubber to a 20,000 gal. benzolized wash oil tank located adjacent to the scrubbers. From this tank the oil circulates in the usual manner through the vapor-to-oil and oil-to-oil heat exchangers, final heater, wash oil still, back into the hot side of the oil-to-oil heat exchanger, and to the hot drain tank. A wash oil decanter tank (12 ft. by 26 ft. by 10 ft. high) is placed in the system before the hot drain tank for the two-fold purpose of partially cooling the oil and removing the dirt and muck from the oil by spraying with cold treated water. A cooling system is being installed for the recirculation of the treated water through this tank. The hot debenzolized oil is pumped from the hot drain tank through 15 banks of wash oil coolers where it is cooled by cold raw water flowing down over the pipes, and flows into a 10,000-gal. circulating tank. From this tank it goes again into the scrubbers thus completing the continuous cycle of circulation.

Separation of the Light Oil

Exhaust steam at 15 lbs. gauge pressure from the booster is used in the wash oil still for distilling the light oil from the benzolized wash oil. The light oil vapors after passing from the wash oil still go through the vapor-to-oil heat exchanger and into a so called primary light oil separator. This apparatus consists of three sections of a fractionating column placed on top of an oil decanter. Cold treated water is admitted in the top section and flows down through the column coming in contact with the light oil vapors passing upward. A portion of the steam and light oil vapors are condensed, the amount depending upon the quantity of water admitted at the top, and pass into the decantor below. The light oil separates and flows by gravity into a storage tank for further treatment. The vapors passing from this apparatus go to the condensers and this condensate flows into a second light oil decantor where the secondary light oil separates and flows by gravity into a second light oil storage tank.



Benzol plant showing final cooler, scrubbers and purifying towers.

The light oil condenser, the pure still and the crude still condensers are all the immersed type. The condenser tank, 26 ft. by 10½ ft. by 7 ft. deep, is supported above the receiver tank platform; it is divided into three sections, two of which contain the condenser sections for the light oil vapors, while the third section contains both the crude and pure still condensers. Raw water is delivered to each section at the bottom of the tank and overflows at the top to the installation of coolers for the treated water recirculating system which is being installed.

The benzol still room contains the two final heaters (one a spare), the wash oil still, vapor-to-oil heat exchanger, primary and secondary light oil separators, crude and pure stills with rectifying columns, dephlegmaters and receiver tanks, the condensers, and a steam driven duplex pump for charging the crude still and the agitator. The pure still charging pump along with the three loading pumps is housed in the loading building located a short distance to the west of the still room. The agitator building is also located adjacent and to the west of the still room and houses the 5,500 gal. capacity cast iron agitator.

The light oil is given a crude separation in the 6,000 gal. crude boiler still into three fractions. The residue of wash oil and naphthalene is pumped to a 5,000-gal. residue tank where the oil is separated and drawn off into the wash oil system. After the acid and caustic treatment, given in the agitator, the crude products are pumped into a 15,000-gal. boiler still and given the final fractionation into pure benzol, pure toluol and pure solvent naphtha. The fractionating columns on both boiler stills are made up of 30 in sections 5 ft. in diameter, the pure still column containing 11 such sections while the column on the crude still is

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Coal and Ash Handling for Steel Plants

The Simplicity and Durability of Devices that Make Use of the Steel Cable Is Brought Out—Horizontal Transportation Problems Easily Solved

By H. S. FORD*

WE will not discuss the necessity of economics of coal and ash handling machinery because this is not a matter of argument. Instead we will confine ourselves to the selection of equipment best suited for the purpose. There are three general classes of conveying and elevating machinery, viz.: belts, chains and steel cables. The advantages and disadvantages of chain and belt conveying systems are well-known and will not be discussed. We will confine ourselves to what might be termed the more modern development of steel cable engineering.

We might say before entering this discussion that conveying machinery, as a class, has been developed much more along the lines of continuous conveying than intermittent conveying. Chain and belt conveyors and elevators are all of the continuous type. Skip hoists and drag scrapers, which are the two types we will describe, belong to the intermittent class. Probably the main reason why the continuous type was first developed was because it is mechanically simple to load, discharge and drive by means of electric motors, any type of continuous conveying equipment. Until automatic electric control had been perfected the reversing type of conveying equipment laid dormant. The mechanical and electrical engineer have perfected control mechanism to such a point in recent years that such equipment is not only reliable, but can almost be called precision equipment.

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The mechanical features involved in loading and discharging the reciprocating type of apparatus are simpler than the loading and discharging of continuous type conveyors. Therefore, the development of the intermittent or reciprocating type of equipment only awaited the perfection of the electrical control.

Perhaps the main difference between the three types of equipment is that both belt and chain equipment consist of a large number of small rollers, links and parts, mounted on a continuous supporting structure. The driving mechanism for continuous type conveyors must be placed at one of the terminals of the conveyor. With the skip hoist the case is entirely different. It consists essentially of a simple steel bucket loaded so that there can be no spill and discharged by inverting the bucket. The driving mechanism in essence is like the driving mechanism for a continuous conveyor except that it does not revolve continuously in one direction. With these essential differences the devices become very different, principally in their simplicity, ruggedness and durability.

The Skip Hoist

Instead of a chain or belt a steel cable is used to transmit the power. To carry material with a skip hoist one or two large, simple and durable buckets are used, instead of a very long rubber belt in one case, and a large number of small buckets with the chain conveyor. This means that because only one or two buckets are used with a skip hoist, the rollers,

FIG. 1—Cable drag scraper, tail block car in the distance.

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axles and lubrication can be well provided for, in order to effect durability and simplicity. The path of the conveying device is very simple with a skip hoist because it consists merely of steel rails. These are not only cheap but they are durable.

The vertical lift of a chain elevator is limited because if the life exceeds 75 ft. the chain becomes large and heavy. The higher the lift the heavier the chain. It is probably impossible to build a chain strong enough, regardless of dimensions, to hang in a mine shaft a half mile deep. With a cable, this is no problem. Further, the cable is very cheap and very strong, and inasmuch as the cable is not called upon to transmit power and carry the material, as does a belt, the problem is further simplified. Dismissing the question of simplicity of loading the skip bucket, and its discharge, as well as the corresponding simplicity and durability of the bucket itself, and tracks and rollers to support the bucket, perhaps a few words as to the essential difference in the problem surrounding the driving mechanism would be interesting.

While the problem of designing the driving unit in any type mechanism is very similar, skip hoists have been developed along lines more acceptable to steel mill engineers. In all cases the driving mechanism consists of a motor with a train of gears and either a drum sprocket wheel or belt pulley driving the conveying mechanism. A skip hoist winder is designed as a self-contained, fully enclosed, high grade compact unit. Because a steel cable is the power transmitting element there is no need whatever of putting the winding mechanism at either terminal of the skip. It is, therefore, a common practice to place the winding machine in a house on the ground.

We sum up by saying that a skip hoist consists of very few moving parts, and these moving parts are very large, well designed and amply lubricated. The skip hoist commonly is adopted for conveying through any path varying from vertical to 45 deg. A modification of the bucket leads the skip hoist to operate at any angle sufficient to insure that the bucket will run down hill without the need of a tail rope.

The Cable Drag Scraper

When the problem involves horizontal transportation in addition to vertical elevating it is common practice to place another drum on the skip winding machine and to attach a car running either horizontally or at a slight incline, to operate in unison with the skip. This auxiliary tram car then becomes an automatic addition to the skip hoist, with all its simplicity and very little additional equipment. The tram car can, of course, be used to collect and bring material to the skip, or it can be placed overhead to receive from the skip and discharge into a long bunker, or in some cases a tram car is used both at grade and overhead. This tram car practice is very commonly adopted by railroads in their coaling stations, primarily because of its simplicity and automatic operation.

For storing and reclaiming coal and such materials in large quantities on the ground, the drag scraper has proven to be a very simple, flexible and efficient device. Before its development the attempt to solve this problem by using either chain or belt conveyors proved inadequate. While either a chain or belt conveyor can stock out material in a large, wedge-shaped pile, they cannot adequately reclaim the stored material. Because of this difficulty the locomotive crane became popular, but its inability to unload cars and railroad tracks necessarily running through the storage area, were serious disadvantages. Further, the locomotive crane, after all, cannot transport the material horizontally. Therefore, railroad cars were commonly employed to effect the horizontal transportation of the material to and fro, over the storage area.

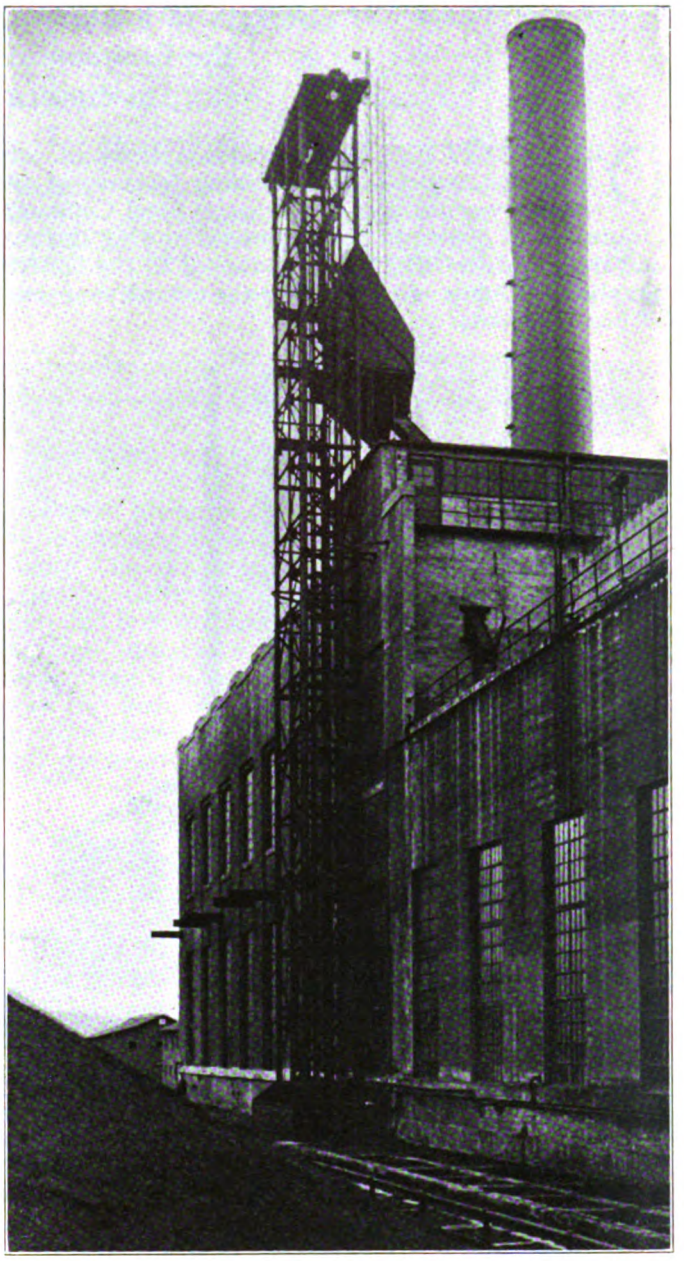

FIG. 2—Double balanced skip hoist.

The cable drag scraper, as originally developed for excavating sand, gravel, etc., showed a simple solution of the problem. By modifying and improving the details it became a very serviceable tool. It is being rapidly and widely introduced to store and reclaim coal over practically any shape or any size area. Fortunately, the contour of this area, and the shape of the area are relatively unimportant. In addition to the cable drag scraper's ability to handle coal and similar materials rapidly and cheaply, it has in the case of coal a very important feature, and that is that coal

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Boiler House Possesses Unusual Features

Coal Is Stored in Silos and from These Transported to the Stokers in a Lorry Car—Plant Design Assures the Economical Generation of Steam

By CHARLES LONGENECKER

ORIGINALITY of design and simplicity of construction are the distinguishing features of the new power plant of the Truscon Steel Company. Originality is shown in the manner of storing the coal and the means by which it is conveyed to the boilers; simplicity is made impressive by the complete absence of non-essentials.

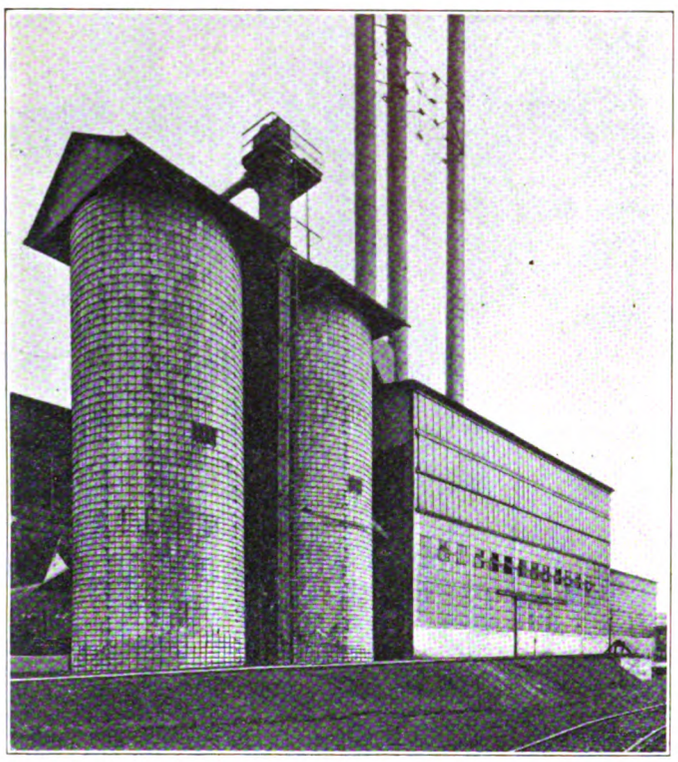

FIG. 1—View of boiler house and coal storage bins.

The plant was erected for the sole purpose of supplying steam for heating the 40 acres of mill type buildings which form the plant. A small quantity of steam is required for process work, such as pickling, but this quantity is so small that it need not be given consideration. For such demands as these, there was no necessity to include much of that equipment which is necessary to a plant furnishing steam for the generation of power over a 24-hour period.

Another feature altogether out of the usual in connection with this boiler house was the ability to obtain all material required in constructing the building from the shops of the Truscon Steel Company. As is well known, this company fabricates steel in a great variety of forms for use in building construction; hence there was available on the grounds all the shapes and equipment desired. The structural steel, such as the columns, trusses, etc., were delivered direct from a shop adjoining the boiler house site while the windows, window sash and roofing supports were of the standard Truscon type and were secured from stock. All erection work, including the foundations, was performed by the company's employees. The ends and sides of the building are of glass, thus providing the maximum effective lighting surface. To further enhance the illumination, many of the interior surfaces have been covered with an aluminum paint, but a paint of some color other than aluminum distinguishes those parts which serve some special purpose such as water and steam valves, etc. The roof is formed of Hyrib lath — manufactured by the company — over which a 2-in. layer of concrete is spread. From the photographs the construction of the building can readily be conceived. It has a width of 40 ft. and a length of 85 ft.

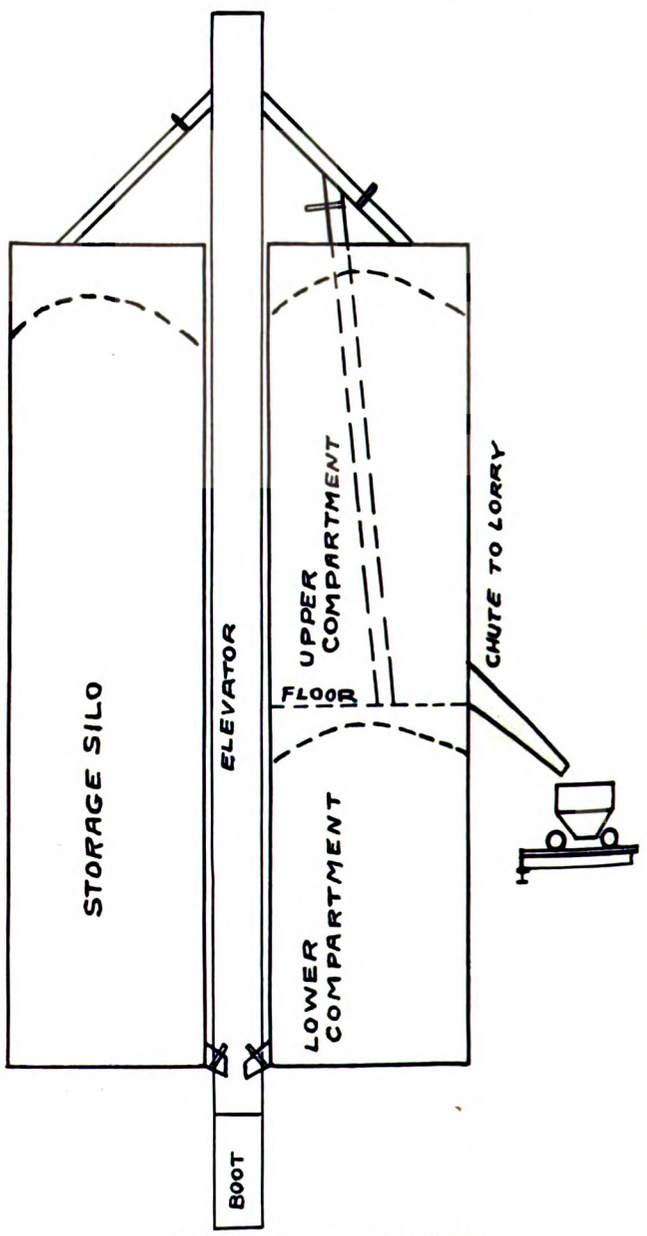

Diagram of movement of coal.

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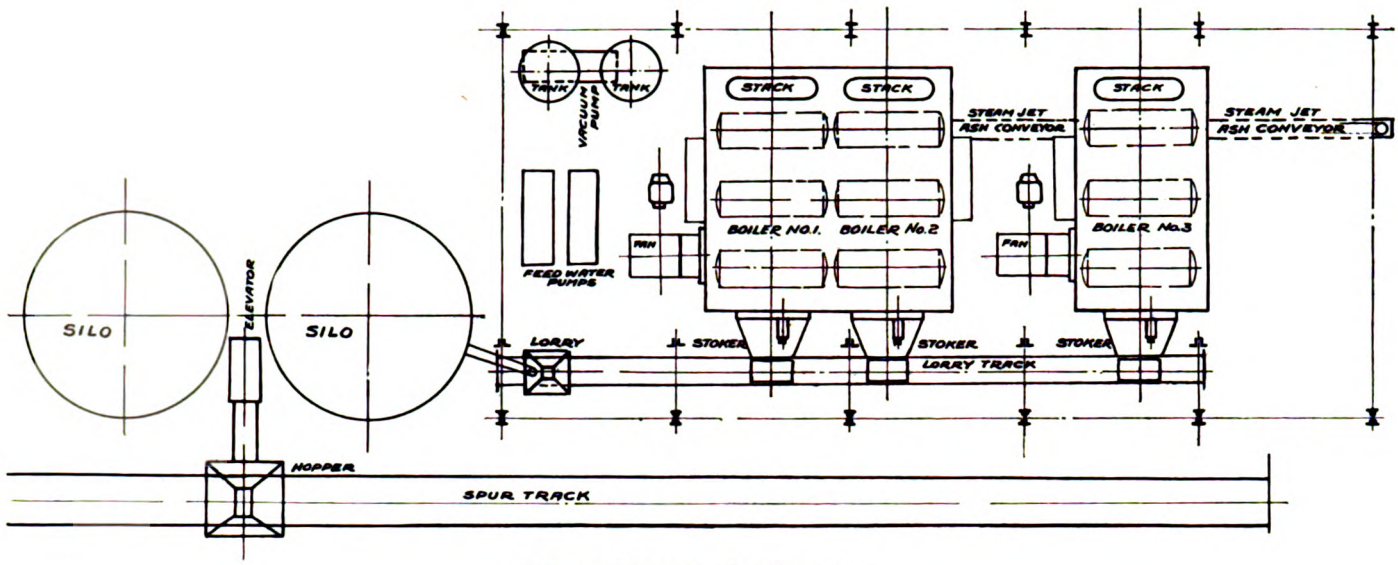

FIG. 2—Diagram of boiler house.

Coal Handling

Coal is received into the system through a hopper located beneath the track and close to the base of the elevator, as shown in the photograph—Fig. 1—and by diagram in Fig. 2. The track passing over the hopper has been extended beyond it in order that additional cars may be held as storage. By placing this track on a slight incline the cars can be released and allowed to move to a position over the hopper. From the hopper, the slack coal is conveyed to the elevator from which it is discharged into either of the two silos through chutes, one of which may be seen at the top of the elevator in Fig. 1. These silos, built of interlocking concrete blocks firmly held together by steel bands, have an inside diameter of 20 ft., a height of 50 ft., and a capacity of 390 tons each.

Coal is fed from the silos into a lorry car—shown in Fig. 2—through a chute which is attached to the silo adjacent the building and which passes into the building at a point such that it can discharge into the lorry car, see Fig. 3.

Each silo has at its base a chute with the discharge end connected to the boot of the elevator, so that coal that has been held in storage may be again delivered to the elevator. Moreover, across the silo adjacent the building a floor has been spread at the point where the chute into the building leaves the silo, thus, this silo is divided into an upper and a lower compartment. From the discharge of the elevator two chutes pass into this silo; one of these chutes terminates at the top of the silo; the other passes through the upper compartment and discharges into the lower. Only one chute discharges into the silo at the left, in Fig. 1.

An arrangement, such as that outlined, provides an exceedingly flexible and economical system for handling coal for a power house of small size, since it is possible to store an adequate quantity of coal and still remove it from storage at an insignificant cost. Moreover, the danger of spontaneous combustion in the stored coal is reduced to a minimum as it can be ventilated by circulation. The operation of the system involves no complicities. Thus, supposing both silos to be filled to capacity they can both be emptied by allowing the coal in the upper compartment of the near silo to be fed to the furnaces. When this compartment is empty the coal in the lower compartment is discharged into the elevator boot, through the chute, and is conveyed into the upper compartment from which it flows into the lorry car. The far silo is emptied in a similar manner: viz., by passing the coal through the chute into the elevator boot and then depositing it into the upper compartment of the near silo. To prevent spontaneous combustion the coal is merely circulated from the bottom to the top of either silo by means of the elevator.

Coal to Boilers

A glance at Fig. 2 makes apparent the method of transporting the coal to the boiler hoppers. After the lorry has been filled from the chute, it is moved to a

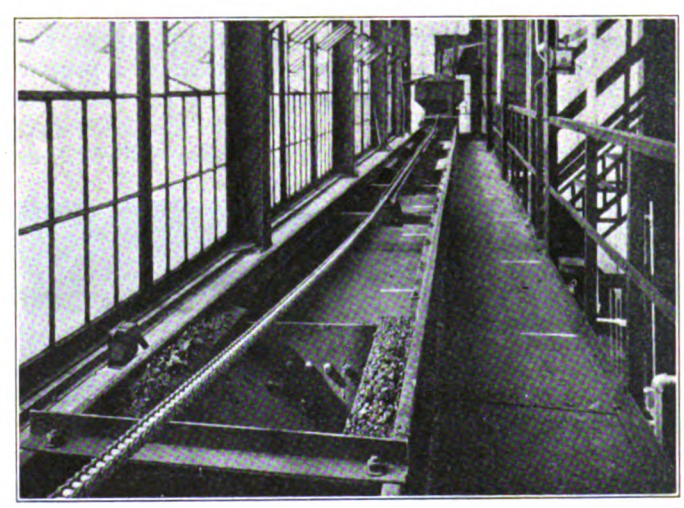

FIG. 3—Lorry car and track.

position over one of the three hoppers and its contents discharged by means of a slide in the car bottom; it is then returned to be reloaded. The lorry is drawn along the track by means of a conveyor chain attached to both ends of the car and passed over a sprocket wheel which is driven through a speed reducer by a motor. Electrical contacts stop the lorry at the ends of the track; other stops at intervening positions are made by "push" bottoms. Whenever the car comes to a stop underneath the loading chute it

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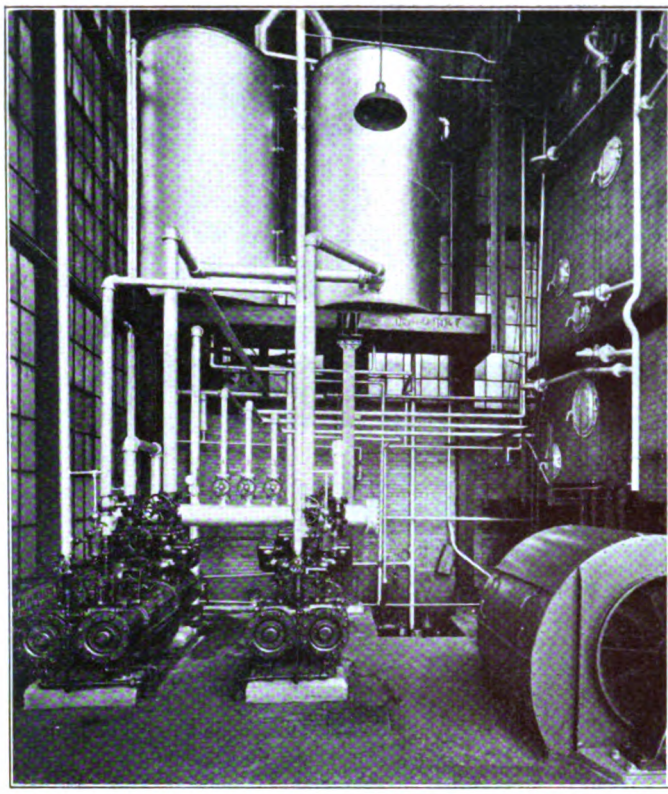

FIG. 4—Tanks and feed pumps.

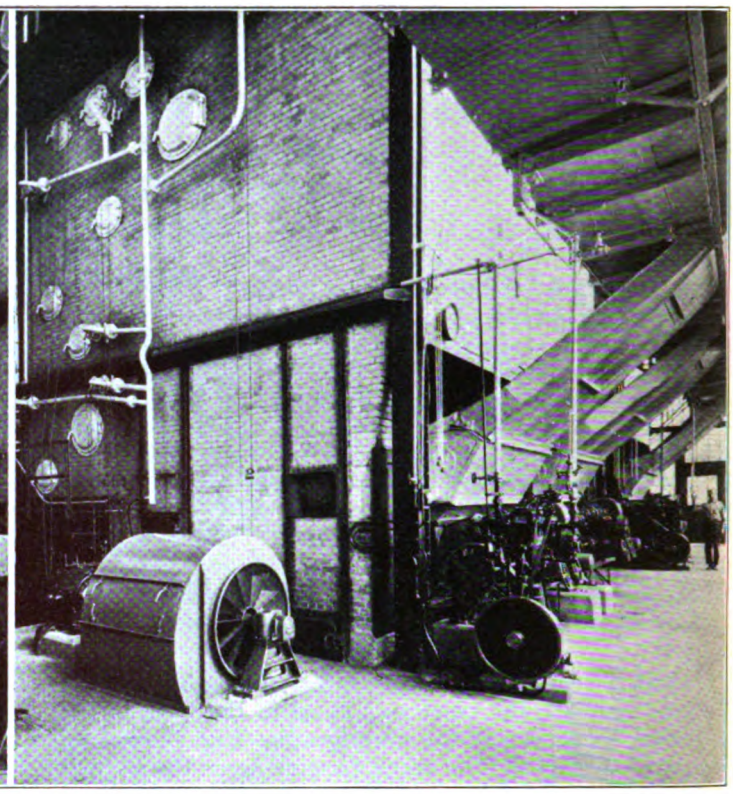

FIG. 5—View of boilers showing fan and stokers.

makes contact with a counter which registers the number of loads transported; therefore affording a check on the quantity of coal burned. Each load approximates 1,600 lbs. of coal. Connection between the stoker and the track is formed by the hopper shown in Fig. 5.

Stokers and Boilers

Steam is generated in three 500 hp., three pass, B. & W. Sterling type boilers, operated at a pressure of 125 lbs. At present steam demands are easily met by these three boilers, but provision has been made for the installation of a fourth boiler should additional capacity be required. The boilers are set with the bottom drum 12 ft. 9 in. above the boiler floor level or 8 ft. 9 in. above stoker floor level.

Each boiler is fired by a five retort underfed stoker driven either by motor or by engine, as illustrated in Fig. 5. These stokers are equipped with ash dumps which are lowered or raised through mechanism connected to steam cylinders. The coal burned is a Pittsburgh vein slack, with ash under 10 per cent and sulphur below 1.75 per cent. Air for combustion is furnished by two fans, one of which appears in the foreground of Figs. 4 and 5. Each fan has sufficient capacity in volume of air to burn all coal fed to the stokers of two boilers when these boilers are operating at maximum rating. Three stacks 5 ft. in diameter by 150 ft. in height carry away the products of combustion from the furnaces. In Fig. 5 the arrangement of soot blowers is obvious.

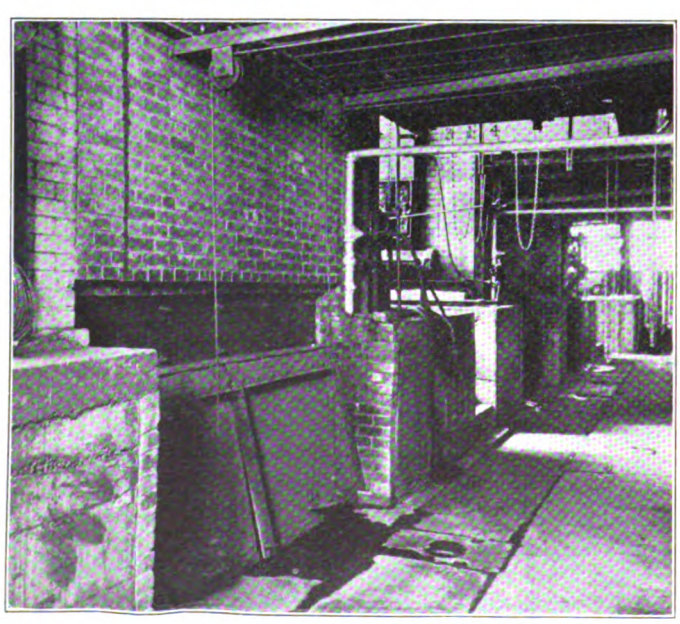

FIG. 6—Ash pit doors and conveyor.

Ash Disposal

When dropped from the grate, the ashes fall into a pit from which they can easily be removed by a hoe. Hinged doors keep this pit sealed, but as these doors are counterweighted they can be readily opened. Fig. 6 illustrates the door construction. Running along the rear of the pits, a steam jet conveyor carries the ashes from the building and deposits them in the yard some distance away. One of the openings into this conveyor is seen directly before the second door in Fig. 6.

Water Supply

Water for the boiler supply is received from the mains of the city of Youngstown, but as the loss of water from the system is very small the quantity of "make-up" water required is likewise small. As the water condenses in the system, it is drawn away by vacuum pumps located below the two tanks shown in

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Truscon Steel Company

Silos	Neff & Fry
Elevator, lorry, etc.	Fairmont Mining Machinery Company
Diamond soot blowers	Diamond Power Specialty Company
Fans	Buffalo Forge Company
Stokers and motors	Westinghouse Electric & Manufacturing Company
Boilers	Babcock & Wilcox Company
Steam jet ash conveyor	George J. Hagan Company
Feed water pumps	Worthington Pump & Machinery Corporation
Engines on stokers	Troy Engine & Machinery Company

Fig. 4. The water then flows into the tanks and from these to the two feed water pumps from which it is forced into the 10-in. manifold and from this into the boilers. In the photograph the discharge pipes, numbered 1, 2, and 3, from the manifold to the boilers are seen directly between and behind the feed water pumps. Two-inch water lines from the city supply enter both tanks and the 10-in. manifold. This water contains from 10 to 15 grains of solid matter per gallon.

Steam was put into the heating system from this plant on December 2, 1926, from which time at least one boiler has been a source of supply. In the warmer months steam is required only for process work hence the capacity of one boiler is sufficient.

Manufacture of Coke at Massillon

(Continued from page 1069)

made up of seven. Individual lines, with removable connections from the receiver tanks to each pure product storage tank, eliminate the danger of contamination of the products due to leaky manifold valves, etc. The storage tanks are located in a row to the south of the benzol building. There are 21 tanks in all, providing 160,000 gals. storage room for crude products and 160,000 gals. for pure products. All tanks containing products with a high freezing point are covered with heat insulating material, which in turn is covered over the top half with galvanized sheet iron for protection against the weather and other abuse.

The following is an approximate average of one month operation, and will indicate the results obtained in the plant:

Tons of coal as charged	34339
Per cent moisture in coal	2.82
Tons of dry coal charged	33371
Tons of coal per oven	13.96
Furnace coke yield, per cent	64.13
Nut coke yield, per cent	6.09
Pea coke yield, per cent	1.38
Breeze coke yield, per cent	4.32
Total coke yield, per cent	75.92
Gross coking time	14 hrs. 21 min.
Net coking time	13 hrs. 44 min.
Total gas, cu. ft. per ton coal as charged	9960
Surplus gas, per cent	62.40
Tar yield, gal. per ton coal as charged	12.29
Sulphate yield, lbs. per ton coal as charged	26.55
Light oil yield, gal. per ton dry coal	3.70
Benzol yield, gal. per ton dry coal	1.79
Pure toluol yield, gal. per ton dry coal	.69
Pure solvent yield, gal. per ton dry coal	.26
Crude heavy solvent yield, gal. per ton dry coal	.11

Coal and Ash Handling for Steel Plants

(Continued from page 1071)

stored by dropping it onto coal or wedge-shaped piles by means of conveyors or locomotive cranes, invites spontaneous combustion. The action of the scraper bucket in stocking out bituminous coal is such that the interstices are filled with fine coal, and it has been found that coal so stored is practically immune from spontaneous combustion. This one feature would be perhaps sufficient to merit its wide adoption, but when its low cost, flexibility, durability and its many other features are considered, it would seem that it is far better adapted to the problem of storing and reclaiming material than any competitive device.

The ability of a cable drag scraper to cover the area is obtained by the use of a tail block car. If it is desired to operate the drag bucket over any or many portions of the field at short intervals the tail block car is equipped with a motor so that it can be moved by power.

Clamshell Buckets in the Steel Industry

(Continued from page 1076)

eral strength. The matter of strength in this connection is important because the bucket scoop depends a great deal upon the lip for reinforcement. All bearings throughout should be of liberal size, not determined particularly by the stress involved but to insure long life. The sheaves in the bucket should be of liberal diameter to prevent excessive cable wear. Where necessary the sheave bearings should be sealed against abrasive materials getting into the bearings. Other pins which are exposed to contact with the materials handled should be sealed, or case-hardened, if sealing is not practicable.

A great many other desirable features might be mentioned if an attempt were made here to give a complete specification on buckets for steel plant uses. However, the points mentioned above will in a general way insure a satisfactory bucket construction, and reduce maintenance cost materially. It is a matter of general experience that replacement of sheave bearings and bucket lips on ordinary buckets represents from 75 to 80 per cent of the maintenance cost.

Adequate digging power, a minimum of moving parts, substantial construction, conditions favorable to long cable life, and the ability to resist wear either by preventing or resisting abrasion, these will make a fitting summary for the above discussion.

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Clamshell Buckets in the Steel Industry

The Construction Features Required to Meet the Severe Conditions of Steel Plant Service Are Here Reviewed — Bucket Weight Important to Efficient Operation

By E. L. HARRINGTON*

THE handling of materials constitutes so great a part of the cost of making steel, that specific material handling problems as they come up are being given increasingly more thought and consideration with a view to selecting equipment of the proper and most suitable type.

The object of this discussion is to deal specifically with that class of material handling problems which require the use of clamshell buckets. The handling of loose or bulk material in and about steel plants cannot be treated generally, because the requirements are so diversified. It is readily accepted that the most severe clamshell bucket work in steel plants is that of handling materials in the open-hearth department; such as slag from in front of the furnaces, broken cinder from skull cracker pits, and dolomite from the stock-yard.

The nature of this particular work is such as to require extremely heavy buckets. In fact, buckets furnished for work of this character weigh twice as much as buckets furnished for ordinary purposes.

The necessity for such heavy weight buckets is attributed not only to the greater digging power required in order to handle this material successfully, but to the severe service and abuse to which such buckets are subjected.

The foregoing applies to the single line hook-on type buckets as well as the direct reeved two-line type buckets. The use of hook-on type buckets has become popular for service under the ladle cranes, because of the convenience of being able to hook the bucket on and off the crane at a moment's notice. The same condition is often found true in the skull cracker pit, where crane facilities will not permit the use of a two-line bucket.

FIG. 1—Clamshell bucket handling slag.

Weight an Essential Requirement

To illustrate the severe nature of this work: When handling cinder from skull cracker pits the bucket often closes on a large piece of unbroken slag buried in the pit. Under these conditions tremendous stresses are set up in the bucket, stresses five or six times greater than the crane hook power. This is due to the multiple reeving in the bucket. To successfully meet this requirement the two-yard single line bucket should weigh from 12,000 to 14,000 lbs. A two-line bucket of the same capacity for this work would not necessarily be heavier than 10,000 to 12,000 lbs., because of the difference in operating mechanism between the two styles of buckets.

There are many other steel plant material handling requirements which are satisfactorily met by using buckets much lighter than these. For instance, handling clay for ladle lining, cleaning out roll mill scale pits, handling coal and coke, and miscellaneous work around the yards. While buckets for this work may not be considered in the class of heavy duty buckets furnished for open hearth service, it is imperative that for steel plant work they be of a comparatively heavy type, so that continuous and uninterrupted service can be expected from them, resulting in a consistently low maintenance cost.

With regard to endurance and low maintenance, there are numerous desirable features that exist in common for all steel plant buckets generally. The scoop cutting lips should be made of some high quality steel, preferably a material which has the quality of resisting abrasion, as well as providing lib-

(Continued on page 1075)

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Magnet Handles Hot Iron and Steel

Advantage Is Taken of the Magnetic Property that Persists Up to Certain Temperatures in Solving Many Difficult Handling Problems

By F. W. JESSOP*

THE fact that iron and steel are magnetic up to 1100 to 1300 deg. F. has long been known, but its importance was not recognized until in recent years when, because of the fierce competition for business and more yet for a fair profit, the time lost waiting for steel to cool was recognized as a big factor in cost. A considerable labor force is required to keep a continuously operated cupola charged. When annealing furnaces have completed their operation they and the steel or castings must lie idle until both cool down to a point where men can handle them. When steel of any kind is rolled it has to lie on cooling beds at great expense until it is cool enough to handle. All of this cooling work is done on expensive tables or in costly furnaces.

The makers of car wheels prodded by competition have been very progressive and it was they who inspired the design of a special charging machine which carried a lifting magnet loaded with scrap or pig iron right into the center of the hot cupola; the machine being also used to push in the necessary coke. The magnets for this purpose were provided with all asbestos insulation and even the terminal insulators were made of asbestos and the leads wrapped with asbestos.

Several such foundry cupolas are now so charged and the saving in labor cost is considerable. A spare magnet is provided to spell off because lifting capacity drops when they get too hot.

Next in line came a steel works which wanted to charge hot ingots into horizontal reheating furnaces and thus save space, time, labor and gas by using a special magnet for this work. The ingots were red hot when stripped and were lifted as soon as they became sufficiently magnetic. The process was successful but it cost the magnet maker a great deal to learn how to make a magnet that would stand up under these severe heat conditions.

Next came the maker of heavy strip steel who was taking his coils of strip from the coiler and handling them on wire rope slings to a big pile where various orders were badly mixed, the one wanted being underneath as usual, and much damage was done to the steel in rehandling.

Steel loses some of its magnetic capacity and so do lifting magnets at high temperature so larger, stronger magnets are required for such duty and to handle this situation two large rail magnets shown by Fig. 2 were specially built to operate under high temperature conditions.

Other steel mills soon availed themselves of this economical method of handling and Fig. 3 shows how well adapted is the standard round magnet for this work saving time, space, labor and gas between successive operations. One large steel plant takes heavy hot billets direct from the shear to annealing furnaces, and the next morning empties the furnace while still hot, thus greatly increasing the capacity of the annealing department. Only the users know how much money is saved compared to the relatively small cost of the magnets as is also true with this method of handling cold iron and steel as compared with old mechanical methods of doing such work.

In as much as steel or iron objects sufficiently cool to allow of magnet handling are still too hot for the approach necessary for making hitches by hand, much earlier removal and transportation can be thus accomplished. As has been brought out special construction of magnets is necessary for the handling of such hot objects and special care must be taken of them.

It might be worth while to point out that magnets for handling hot material are not filled with asphaltum compound because it would soon evaporate, so they are not waterproof and should never be exposed to water or used for outside work.

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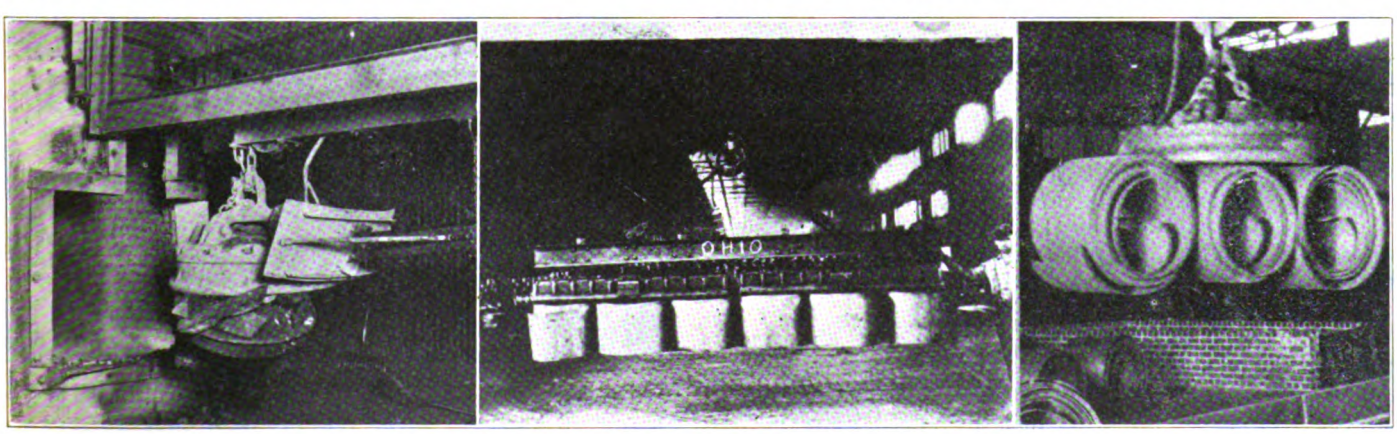

FIG. 1 (left)—Shows a magnet supported by a special boom charger serving a continuously operated cupola. FIG. 2 (center)—Shows two 26 in. x 60 in. rectangular magnets supported end to end on a beam for handling coils of hot strip steel. FIG. 3 (right)—Shows a 55-in. diameter round magnet specially prepared for handling a variety of sizes of hot strip coils on their sides.

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The Place of the Small Hoist Equipment

Handy and Efficient, Inexpensive in Operation, These Accessories Give an Uninterrupted Service on Many Operating Jobs or Meet the Occasional Special Demand

By J. R. MILLER

STEEL mill operations are usually thought of in terms of large units and heavy installations. Not enough thought is, in general, given to the small items that make up the general plant efficiency. It is in connection with these small units of the operation that the small hoist fits into a place of great usefulness and indispensability.

By the small hoist we mean any of the equipment covered by the following classification:

Chain blocks,
Air cylinder lifts,
Air driven hoist drums,
Electric driven hoist drums.

These may hang from a fixed support simply, being placed there as occasion may arise, or hanging there permanently for a specific use; or they may hang from a jib crane swinging over the area to be served; or they may be supported on a trolley running on a track over a fixed path or paths. Therefore the small hoist being confined to a more or less limited area of travel and having small load capacity is limited in its application to certain definite fields.

When any certain application is worked out, however, they are efficient in that application, and they supply a place not filled by standard crane equipment or they relieve such equipment of frequent small lifts that interfere with their service of more important operations. Not enough use is made of this type of hoist in the general run of steel plants.

Wherever the load is small and the paths of its movement fixed the small hoist is the most efficient means for its transportation. It is poor practice to load up the time of a large overhead crane with a lot of small lifts while its important heavy lifts are delayed. Also it is not economy to lengthen the time of a repair for the lack of a chain block or air hoist handy at the job.

In the blast furnace plant and in the open-hearth and Bessemer plants there are many places where the use of the small hoist facilitates repairs. Often it is a good plan to keep one hanging up over a point where repairs must be frequently made. Also, where certain materials follow a fixed path of transit in the shop, a monorail, out of the way of regular paths of heavy transportation, facilitates the transfer of such materials and adds to the efficiency of the shop cranes as a whole.

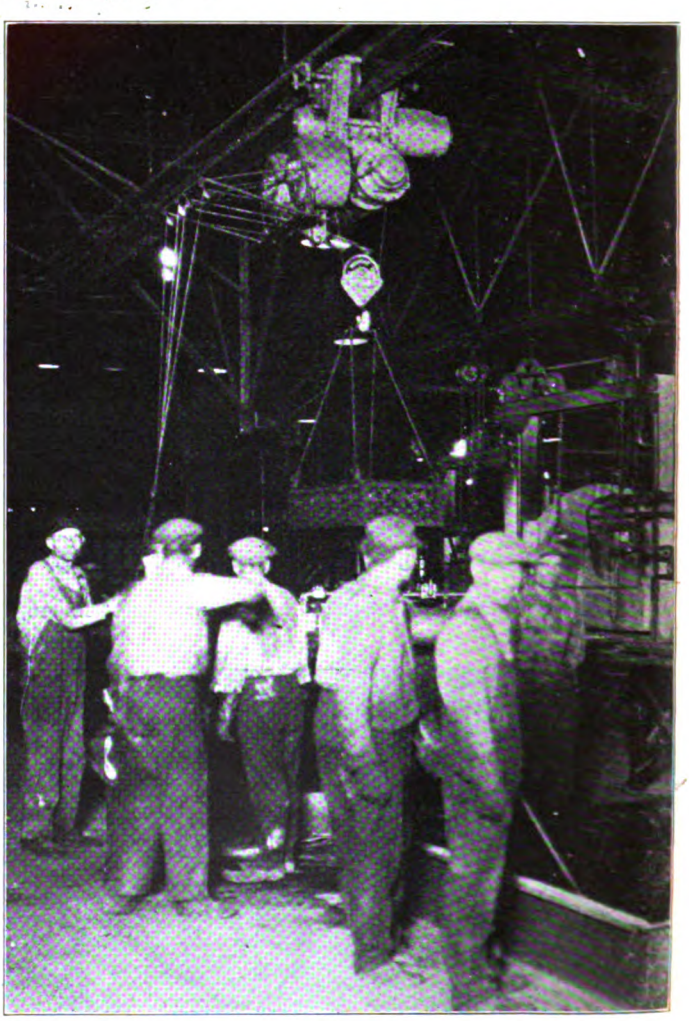
In the blooming mills the small hoist finds application mostly for mechanical repairs, however, in the billet yard where individual blooms may have to be moved for cutting or chipping there are certain places for its use in regular production.

In the rolling mills and finishing and shipping yards, there are a great many applications including mechanical repairs and the service of finishing machines. Certain small mills use the small hoist both in charging and drawing billets and in handling finished product.

In the foundry a properly designed layout employing jibs and monorails is very efficient and increases the production on the molding and cleaning floors, and especially over molding machines where the constant service of a lift is essential. Where castings are loaded out on small buggies as is the case in a steel mill foundry this can be done by means of the air or electric operated hoist so that overhead cranes are free to do heavy work.

Machine tools served by an individual lift accomplish more work than if they must wait for service from the heavy crane equipment. This is equally true of finishing machines in the shipping yards and mills.

Repair crews and millwrights seldom have enough small hoists to properly facilitate their work. The time saved on a single job often fully covers the cost of such equipment.



Being controlled and operated from the floor there is seldom need for a special craneman and so the cost of operation is very small, while the service is immediate. Speed of lift as required can be made a basis of judgment in selecting the equipment and a proper kind of hoist to be used for the job contemplated.

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Link Belt Announces a New Two-Yard Shovel

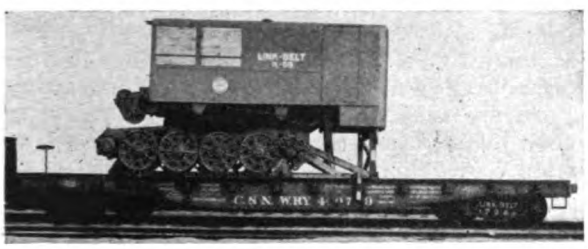
(Continued from page 1054)

The Link-Belt K-55, as the new machine is known, is a powerful, heavy duty, all-purpose, 2-yard machine, primarily designed for the following adaptations:

Shovel with 30 ft. boom and 18 ft. dipper stick carrying a 2-yard struck-measure-capacity all-manganese steel dipper.

Dragline to handle 2-yard dragline bucket, for medium and medium-heavy excavating, on boom 50 ft. long; or a 1½ yard dragline bucket on boom 60 ft. long.

Clamshell Bucket of 2-yard capacity, for sand, gravel or materials of equal weight per cubic foot, and



consistency, on boom 50 ft. long; or a 1½-yard bucket, in such materials on boom 60 ft. long; or, of course, an equivalent weight of loaded bucket in heavier or lighter materials.

All attachments are interchangeable without removing or disturbing the mechanism of the machine proper. A special clearance reducing arrangement contributes to making the machine a particularly convenient one for the contractor, by making it possible to ship it from place to place without dismantling, thus saving hundreds, and often thousands, of dollars, and many days' time, every time the machine is shipped to a job.

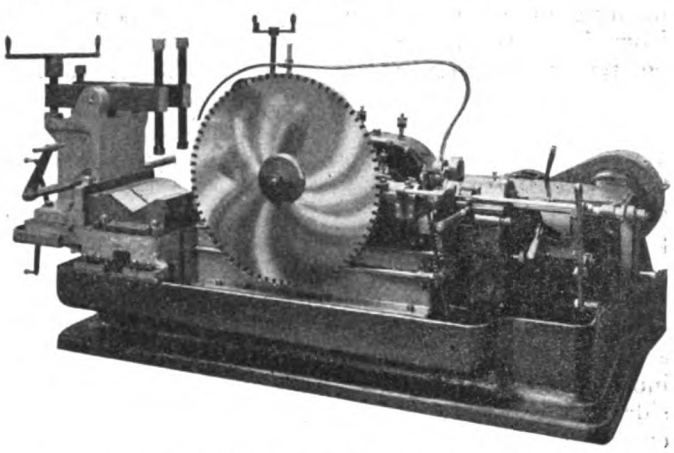
Besides the unit cast steel construction of lower and upper frames; self-cleaning crawler treads and large bronze-bushed crawler rollers, enclosed cut gearing and bronze-bushed bearings throughout—features which Link-Belt Company has pioneered since they first began to build crawlers, other details of construction which are outstanding and indicative of the caliber of the new machine, include: Internal expanding friction clutches of unusual size and power, the main drum clutches being 42 in. in diameter; and swing and travel clutches, 30 in. diameter; a 13½ in. diameter center pin, adjustable from above, which can be removed as a unit with the vertical travel shaft assembly, without removing any other parts; large drums with renewable cast steel shells, having air space between clutch and brake surfaces, for rapid cooling; and large, powerful drum brakes, 48 in. diameter by 5 in. wide.

The machine in working condition is 12 ft. wide overall at the lower frame, which gives it ample stability for the work for which it is designed. Crawler treads are 36 in. wide. The K-55 is built to be driven with gasoline engine, electric motor or Diesel engine drive.

A New "Cobly" Saw

Considering a saw blade to be a milling cutter the machine shown is designed and built as a modern high grade machine tool with the objective of a low cost per 1000 in. of metal cut. It is designed to use either a 42-in. or 48-in. blade. The 42-in. blade will cut through a 15-in. bar, and the 48-in. blade an 18-in. bar without turning.

The saw arbor is 6 in. diameter hardened and ground and fitted into a lapped bearing located close to the bed. The carriage is cast solid around the ways and fitted with adjustable taper gibs to compensate for wear. To insure perfect alignment and fits, the bed is first scraped to precision surface plates. The feed screw is mounted above the ways in line with the center of the saw arbor and close up to the saw blade in line with the cutting and frictional resistance to eliminate vibration because of cant or side pull. The feeds are geared and positive and the 12 changes range from ¾ in. to 3¾ in. per minute. The machine is driven through hardened nickel steel arbor gear and pinion having herringbone teeth and running in a bath of oil. The worm is hardened steel and the worm gear phosphor bronze. The machine has a sliding gear transmission through steel gears running in oil, giving three changes of 45, 60 and 75 ft. per minute. It is driven by a 25-hp. constant speed motor through a powerful friction clutch which is controlled by levers placed at both front and rear of machine at which points are also levers and cranks for start, stop and reverse of feeds and adjustment of carriage to and from the work. Adjustable stop collars are provided to automatically stop and reverse the feed giving quick return of the carriage to a point where the blade clears the bar being cut. The friction clutch permits quick stopping of the blade without stopping the motor and eliminates the chances of damaging the blade by moving a loose bar in vise while blade is in motion.



A recent test of this machine showed very accurate and economical results cutting a 15-in. bar of low carbon steel in 10 minutes, a 10-in. bar in 4½ minutes, and a 6-in. bar in 1¾ minutes, or at the rate of about 18 sectional inches per minute, the blade used being 42 in. in diameter with 5/16-in. kerf. Floor space required when belt driven is 69 x 141 in., and with motor 84 x 141 in. The machine is built by The Cochrane-Bly Company, Rochester, N. Y.

New Koppel Air Dump Car

The Koppel Industrial Car and Equipment Company of Koppel, Pa., a subsidiary of the Pressed Steel Car Company, recently completed an improved design, all steel 100,000 lb., 30 cu. yd. capacity automatic rolling trunnion air dump car, class RTD-30.

The car weighs 66,000 lbs. and has a length inside of body at top of 34 ft. and width of 9 ft. 3 in. The

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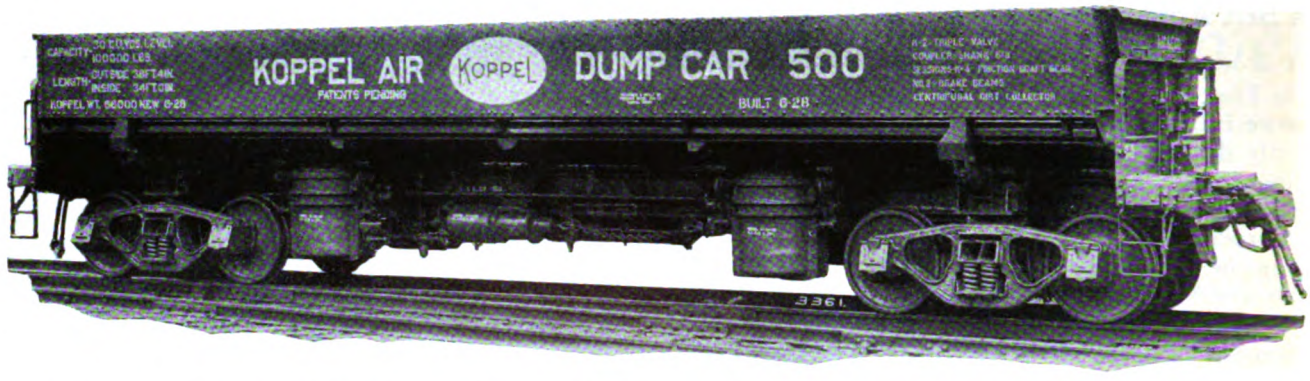


length inside of bottom is 32 ft. 4 in. and the width 8 ft. 10½ in.; and the depth inside of body is 2 ft. 8½ in. The length over striking plates is 38 ft. 4 in., the overall width 10 ft. 3⅞ in., and the height 7 ft. 9 5/16 in. The dumping angle of the body is 45 deg., the wheels are 33 in. ARA chilled iron, the axles 5½ in. and 10 in. ARA and the gauge is 4 ft. 8½ in.

A feature of the design is that the entire weight of the car body and lading is carried in stable equilibrium directly on the center sills without the use of trunnions. This is accomplished by rolling diaphragms built into the bolster constructions located centrally on truck centers and by four rolling diaphragms, one located at each cross bearer supporting the air cylinders.

The direct bearing surface between the body and underframe members extends 25 in. on either side of the center of the car, and when air is applied in the lifting cylinders the car body rolls from a point 25 in. from the center until the upper stops at the end of the bolsters and diaphragms engage the lower turning seats attached to the underframe.

Another feature is an interlocking cast steel stop device just back of each underframe bolster to prevent transverse and longitudinal movement of the body due to rough handling, preventing damage to the piston rods and other parts.

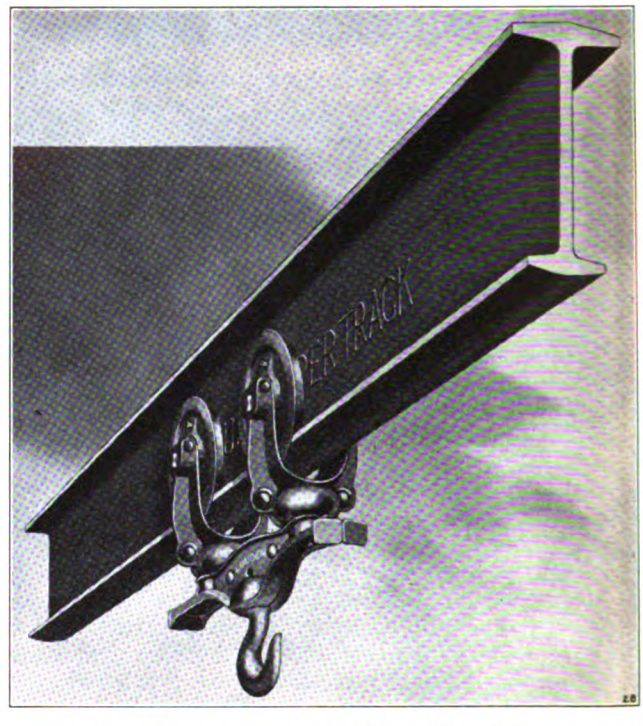
The dumping of the car is controlled by three valves. The indicator valve, which indicates the side on which the car is to be dumped is manually set by a rod passing across the car at the ends of which are index plates. This valve can be set to dump on either side or neutral. The operating valve is located at one end of the car, and when opened admits air to the set of cylinders on the side for which the indicator valve is set, dumping the car. The operating valve handle can be locked in a closed position when necessary. The control valve allows the cars to be operated in trains from the operating valve of any car selected in the train, and by proper setting of the indicator valve any car or cars in the train can be controlled as desired.

New Overhead Trolley Track

The Louden Machinery Company, Fairfield, Iowa, has recently brought out a heavier line known as Louden Super-Track. Carrying capacity is rated as 3000 lbs., which allows a large margin of safety.

This new overhead trolley track is a special section, approximately 6 in. deep with a 3-in. flange at the top and a 2 -in. flange at the bottom. Unlike ordinary I-beam it is specially rolled, both as to form and material, for service as a trolley track. Special features also distinguish the new two-way, three-way, cross-track and turntable switches designed for use with the super-track system.

In a majority of cases it is believed that this super-track monorail will provide its own superstructure, being merely suspended on hangers attached to the overhead joist, girder, truss or ceiling framework. Installation costs, therefore, should be lessened. As the



hangers may be spaced a considerable distance apart, it is conceivable that installation should be simplified and made practical where wide areas between roof trusses must be spanned.

There is sufficient space between hanger grips and trolleys to prevent all possibility of the two coming into contact, on swinging loads. The carrying capacity of the track, under actual test, is placed at 3,000 lbs., with adequate margins of safety, and the track is available in straight lengths and curves, with switches, cross-overs and all necessary fittings for any particular requirements.

1926 and 1927 Issues

A request has been received for complete sets of the 1926 and 1927 issues of Blast Furnace and Steel Plant. Will any of our readers who have these issues and care to dispose of them please notify Steel Publications Inc., 108 Smithfield Street, Pittsburgh, Pa.

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TRADE PUBLICATIONS

The Link-Belt General Catalog 500, published by Link-Belt Company, of Chicago, Indianapolis and Philadelphia, consists of 1088 pages and not only covers in engineering data and list prices, the complete chain, sprocket, power transmission, elevating and conveying and engineering divisions of that company's business, but contains considerable data for which the engineer has use.

In developing this book, it was the purpose not only to make its contents of engineering information so ample that engineers might design plants of a standard character without aid, but also to supply price lists so complete as to enable the experienced buyer to determine net prices of his purchases.

In addition to being an unusual engineering catalog, it is a text book of the conveying, elevating and chain transmission art.

* * *

E. J. Lavino & Company in bulletin 1-2-A present some useful information concerning the relative cost of chrome and magnesite brick. The cost of these bricks are tabulated under the headings, cost per square foot and per cubic foot and cost per 1000. The use of chrome brick is advocated. Bulletin 1-17-12 from the same company gives mixing directions and uses for Kromepatch.

* * *

"Lubrication" is the title found on the cover page of an eight-page booklet describing the oils sold by The Hodson Corporation of 326 West Madison Street, Chicago. This company is a manufacturer of gear and shaft lubricants, cutting, quenching, and tempering oils.

* * *

Bearing the title, "The Riley Atrita Unit Pulverizer" a bulletin of 28 pages gives a very complete description of the pulverizer and burners installed for burning powdered coal under boilers. Illustrations are plentiful and with the text afford a very clear conception of the construction of the equipment and the manner of installing it. Copies may be obtained from the Riley Stoker Corporation, 9 Neponset Street, Worcester, Mass.

* * *

"Gas Regulation of Coke Plants" and "The Regulation of Coke Plant Stack Draft" are the titles to be found on two very attractive bulletins which can be secured on request to the Shallcross Control Systems, 1195 Thirtieth Street, Milwaukee, Wis. The first mentioned bulletin "is descriptive of different types of regulators for use in automatically controlling the gas make in a coke plant." The latter bulletin describes an automatic control for maintaining a uniform draft on the waste gas flue of a coke oven battery.

* * *

"To Help You See Us As We See Ourselves," is the introductory statement on the cover of a pamphlet in which is enumerated the equipment manufactured and service rendered by the Shaw Crane-Putnam Machine Company. This company was formed in October 1927 to care for the engineering and manufacturing interests of Manning, Maxwell & Moore, Inc. The company manufactures electric traveling cranes, machine tools, etc.

Purfeco is the trade name given by the Pulverized Fuel Equipment Company, of Rockford, Ill., to its system of powdered coal firing as explained in Bulletin No. 3. A unit pulverizer is offered for comminuting the coal.

* * *

The Electric Machinery Mfg. Company, of Minneapolis, on leaflets No. 301 and 302 present the distinguishing features of the E-M static condensers.

* * *

In two reprints T. A. Marsh, western engineer of the Combustion Engineering Corporation, discusses the "Design and Application of Traveling Grate Stokers and Forced Draft Chain Grates." The application of these methods of firing boilers, the fuels burned and the results obtained are explained at considerable length.

* * *

Bulletin No. 9 the Grindle Fuel Equipment Company, of Harvey, Ill., presents information concerning the savings obtained by burning powdered coal under boilers and malleable iron melting furnaces. The Grindle multi-stage unit pulverizer is recommended for powdering and delivering coal to both these types of furnaces.

* * *

Uses for Sil-O-Cel insulating materials and allied products are listed at some length in bulletin No. 101 compiled by the Celite Products Company. The manner, the bricks and material is shown by illustrations.

* * *

A bulletin mailed by the Milwaukee Locomotive Manufacturing Company, of Milwaukee, gives detailed information concerning the construction of the type "H" gasoline locomotive manufactured by that company. A description of other types will be found in the same bulletin.

* * *

The third edition of the "Sheet Iron Primer" can be secured from the Central Alloy Steel Corporation, Massillon, Ohio. On the 63 pages which make up this primer is related in an interesting manner the procedure followed in separating the iron from the ore and the conversion of the resultant metal into sheets. The booklet is obviously non-technical.

* * *

The advantages of the continuous type of air filter, as manufactured by the Reed Air Filter Company, of Louisville, Ky., are set forth in Bulletin No. 116. This filter is automatically self cleaning. Sizes, capacities and dimensions are listed. Other types of filters are manufactured by this company.

* * *

Manganese is the subject of an address delivered by J. Carson Adkerson at Butte, Mont., at the opening of the nodulizing plant of the Domestic Manganese & Development Company. Copies may be obtained from the American Manganese Products Association, Washington, D. C.

* * *

Plastic K-N, a chrome ore refractory, has its properties and uses presented in a leaflet prepared by E. J. Lavino & Company, which company manufactures it. This plastic refractory finds application in the repair of furnace linings and hearths. The leaflet illustrates the manner of making furnace hearths, gives instructions for the use of K-N and presents data concerning its shipment, etc.

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TRADE NOTES

Gears & Forgings, Inc., Cleveland, Ohio, manufacturers of gears, forgings, speed reducers and special machinery has appointed Potter & Dugan, Inc., Erie County Bank Building, Buffalo, N. Y., as district sales representatives for Buffalo and vicinity.

* * *

The Brown Instrument Company, of Philadelphia, makers of industrial and power plant indicating, recording and automatic control instruments for measuring temperature, pressure, fluid, flow, machine speed, per cent CO_2 in furnace flue gases, etc., is building another addition to its plant. The new structure will be 60 ft. long by 44 ft. deep and two stories in height. heavy foundations will permit other floors to be added as future requirements may demand. Construction will be strictly fireproof throughout. The rapid growth of the company and the cnlargement of its line has made necessary this latest plant addition, the third within eight years. Its primary purpose is to provide research facilities commensurate with the needs imposed by the rapid expansion of the company's interests with respect to variety of products and the continually widening application of Brown instruments to the activities of industry and science.

* * *

Illinois Steel Company have awarded contract to Arthur G. McKee & Company, engineers and contractors, for a new stock house and material handling system at their Nos. 3 and 4 blast furnaces, Joliet, Ill.

The stock trestle and bin structure will be approximately 400 ft. long., and will include two coke bins and 39 ore and stone bins of the Baker suspension type, equipped with McKee special continuous opening segmental hand operated gates. Three larry cars of the latest improved design will also be provided.

* * *

Gibb Welding Machines Company, of Bay City, Mich., manufacturers of arc, spot, seam and butt welders, has increased capital stock by $125,000 making a total of $250,000.

* * *

An intensive study of conditions in the San Francisco Bay region during the past six months by the Pacifiic Coast Steel Company in conjunction with the industrial engineers of the Chamber of Commerce, convinced the company there is need and room for a machine bolt, nut, rivet and specialty forging plant. The company decided that this plant will be built immediately. It will be adjacent to its big steel plant at South San Francisco. John Stetter will supervise and direct operations in the new plant. Mr. Stetter is well and favorably known to all bolt product manufacturers and consumers, having headed several of the largest and most progressive plants in the East.

The plans for the new plant show that the manufacturing department will be housed in a steel building 450-ft. long by 100-ft. wide, part of which will be three stories high, while the machine shop and electric tool heating department will be 150-ft. by 80 ft. All equipment will be modern. A full line of standard bolt products will be manufactured. The line of specialty forgings will be cared for as the market develops.

The Ashland Division of the American Rolling Mill Company have ordered three 300-hp. oil-electric locomotives to be built jointly by the Ingersoll-Rand Company, General Electric Company and American Locomotive Company.

* * *

Botfield Refractories Company, Swanson and Clymer Streets, Philadelphia, Pa., announce that, effective June 1, the distribution of their well-known products, Adamant Fire Brick Cement, Adachrome and Adachrome Fines and The Adamant Gun for Toledo, Ohio and vicinity will be handled by The Builders & Industrial Supply Company, 4090 Detroit Street, Toledo, Ohio.

* * *

David Lupton's Sons Company, of Philadelphia, has contracted with the Clearing Industrial District to immediately erect the first unit of their new Chicago manufacturing plant and warehouse.

The plans contemplate the development of a Lupton plant at Chicago covering approximately six and one-half acres at Clearing. The first unit already authorized, will be 500 ft. long by 150 ft. wide, located upon a tract of 93,881 sq. ft. Additional land required for the ultimate expansion to a plant 1,000 ft. long by 300 ft. wide is provided for. The entire six and one-half acres is served by switch-tracks from the Belt Railway of Chicago.

* * *

Ottawa Sands Corporation, a division of the Material Service Corporation, 1751 Conway Building, Chicago, Ill., announce the erection of a new and advanced silica sand producing plant to be in operation September 1, 1928.

The First Iron Works in America—1645

(Continued from page 1036)

imprisonment, later went to England to clear himself with his former employers, which he apparently did. Among the papers is an affidavit, showing that William Awbrey was short £600 in his accounts as confessed by him in London, which may explain Gifford's rehabilitation. Later he returned to this country and took up some land.

The works continued to operate but under more difficult conditions, for they had to go as far as Reading for their ore. They were controlled finally by Mr. William Paine, the inventory of whose property after his death in 1660 contained the item: three-fourths of the works at Hammersmith and Braintree for £800. His son mortgaged them to the Appletons to fulfill the terms of his father's will and about 1688 they ceased to exist.

Workmen trained here went to other places in the colonies as new plants were started. Here Joseph Jencks, who also had a wire mill, invented the modern form of scythe. It was here the skill to cut the first die for the "Pine Tree" shilling was developed.

Here also worked Henry and James Leonard, of whose descendants it was said, "Where you can find iron works, there you will find a Leonard," and from this first venture came a long line of able, adventurous and farseeing men, who at present are so truly represented by the members of the American Iron and Steel Institute.

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NEWS OF THE PLANTS

Ohio Seamless Tube Company, Shelby, Ohio, will build additional plant units to accommodate increased airplane and automotive business, including a boiler house, additions to the pickling department, 25 additional benches for the manufacture of airplane tubing and several new cranes.

* * *

The Mannesmann Tube Company expects to open up new works at Huckingen toward the end of the summer. These works will comprise three blast furnace stacks, one basic Bessemer steelworks, rolling mill and various shops.

* * *

The Bethlehem Shipbuilding Corporation, Ltd., Bethlehem, Pa., has recently let a contract to the Austin Company, Philadelphia, for a machine and fabricating shop, a wood working shop, a pattern shop and control house at the ship repair plant on Key highway.

* * *

The Bayonne Bolt Corporation, Second Street, Bayonne, N. J., will build a one-story plant, 50 x 287 ft. on West First Street.

* * *

The General American Tank Car Corporation, has designed a special car, weighing 200,000 lbs., for transporting helium gas for use in United States dirigibles. The navy department has accepted the design and placed an order with the company.

* * *

The New York Central Railroad will install a second coal dumping machine at the Ohio Central dock at Toledo, Ohio. The style of machine has not yet been selected, but it is expected to be in operation in 1929.

* * *

The Sessions Engineering Company, Chicago, and Detroit, is drawing plans for the new plant to be built by Steel & Tubes Incorporated, Cleveland, at Ferndale, Mich., a suburb of Detroit. Contracts have been let and the plant is to be making light gage electric welded steel tubing about the end of the year.

* * *

The Colonial Iron Company, expects to blow in its furnace at Riddlesburg, Pa. The furnace has been relined and is ready for operation, but will not be lighted until the company has installed a coke screening device now on the ground and until the overhauling of its mine equipment has been completed. The furnace will produce foundry iron.

* * *

A minor explosion in the boiler house stack and a break in the water line hampered production of pig iron at Witherbee, Sherman & Company's plant, Port Henry, N. Y., recently. However, the furnace is operating again as usual.

* * *

Officials of the Youngstown Sheet & Tube Company, are considering the installation of equipment for making electrically welded pipe in large diameters from plates. Should plans be approved, the proposed equipment will absorb most of the idle plate mill capacity at the company's Brier Hill division.

Steam Unit for Smithsonian Institute

A one-twelfth scale model of an Erie City Steam Unit, comprising boiler with the economizer water-cooled furnace and pulverized coal firing unit, will be placed in the Division of Mechanical Technology in the Arts and Industries Building, Washington, D. C. This model was built at the request of the Smithsonian Institute. It is constructed with the intention of clearly illustrating present day practice in the design of steam generating equipment.

COMING MEETINGS

Aug. 29-Sept. 2—Eleventh annual conference on Human Relations in Industry, at Silver Bay, Lake George, N. Y. Fred H. Rindge, executive secretary, 347 Madison Avenue, New York City.

* * *

Sept. 4-7—Canada's second steel and power show, University of Toronto Arena, Toronto, Ont. Campbell Bradshaw, executive director, 24 Front Street, West, Toronto.

* * *

Sept. 17-20—American Society of Mechanical Engineers, second national fuels meeting at Cleveland, Ohio. Calvin W. Rice, secretary, 29 W. Thirty-ninth Street, New York City.

* * *

Sept. 24-Oct. 6—World Power Conference, Fuel Conference at the Imperial Institute, London. The Secretaries, 36 Kingsway, London W. C. 2, England.

* * *

Oct. 1-5—National Safety Council, seventeenth annual safety congress at New York City. Idabelle Stevenson, executive secretary, 1 Park Avenue, New York City.

* * *

Oct. 8-12—American Society for Steel Treating, tenth annual convention and national metal exposition at Philadelphia. W. H. Eisenman, secretary, 7016 Euclid Avenue, Cleveland, Ohio.

* * *

Oct. 8-12—American Welding Society, annual fall meeting, Philadelphia. M. M. Kelley, secretary 33 West Thirty-ninth Street, New York City.

* * *

Oct. 8-12—Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, annual fall meeting, Philadelphia. W. M. Corse, secretary, 810 Eighteenth Street, N. W., Washington, D. C.

* * *

Oct. 11-13—American Gear Manufacturers' Association. Semi-annual meeting, Statler Hotel, Buffalo. T. W. Owen, secretary, 3608 Euclid Avenue, Cleveland.

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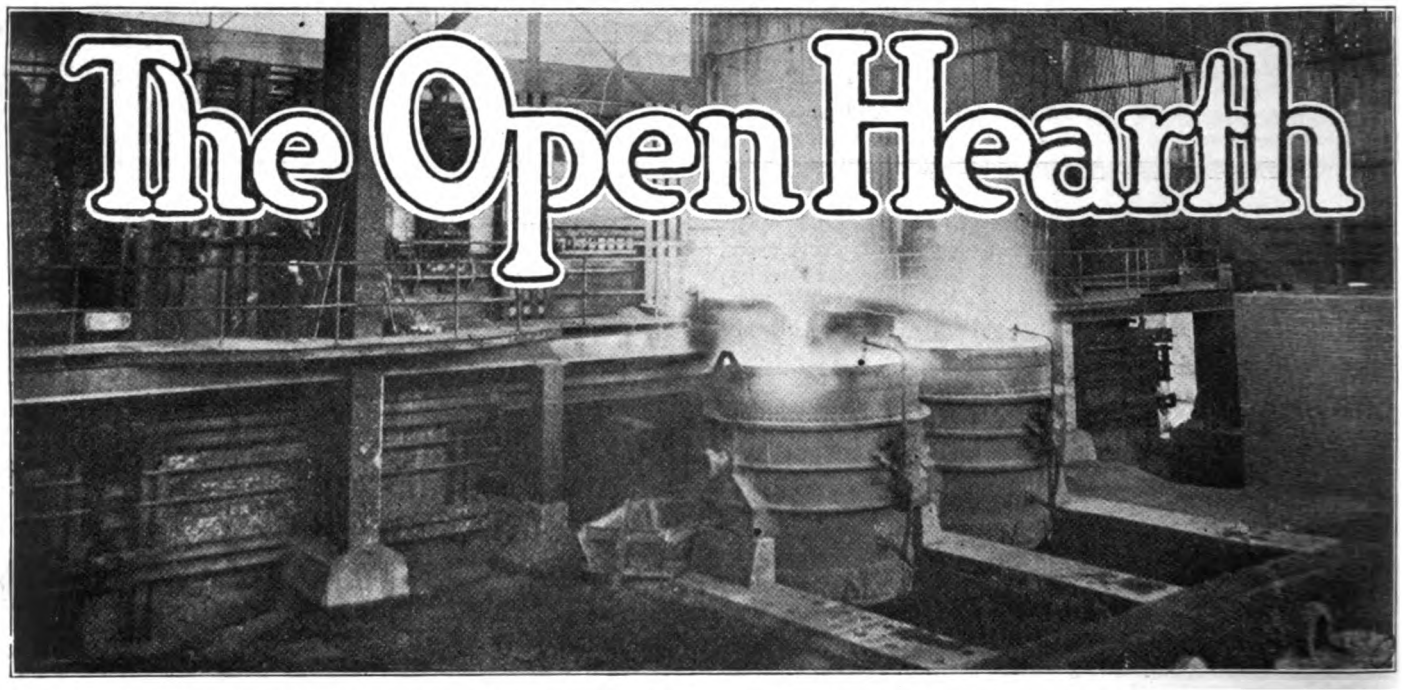

J. J. Seaver, vice president of Arthur McKee & Company, engineers, Cleveland, and for 15 years a member of that company, has become vice president of H. A. Brassert & Company, Chicago, engineers.

* * *

Leonard E. Schlemm was made a member of the boards of the Lake Superior Corporation, and of the Algoma Steel Company, at the Montreal meeting a few days ago. Mr. Schlemm, a civil engineer, has practiced as a consulting engineer at Montreal for 18 years.

* * *

Fred C. Young, district manager of the Cleveland territory for the Union Drawn Steel Company, Beaver Falls, Pa., has been appointed assistant general manager of sales, effective July 2, assisting George B. Mitchell, vice president in charge of sales. Mr. Young has been affiliated with the Union Drawn Company almost 14 years, having previously represented that company in Detroit. A. C. Geldner, assistant to Mr. Young in the Cleveland district for the past five years, has been appointed to succeed Mr. Young.

* * *

Ludwig Kemper has been made president of the Cincinnati Ball Crank Company, Cincinnati, succeeding Clifford Green, who has been made chairman of the board. Mr. Kemper was at one time vice president of the Otis Steel Company, Cleveland,

* * *

Lawrence W. McNamee, auditor of the Illinois Steel Company, Chicago, has resigned, and is to be succeeded by A. M. Roberts. Mr. McNamee also gave up his duties as president of the Gary State Bank, Gary, Ind. He will be succeeded in the latter post by W. W. Gasser of Marquette, Mich.

* * *

J. R. Lovejoy, vice president who has served the company 42 years, George F. Morrison, vice president associated with the company 45 years, and B. G. Tremaine, one of the organizers of the National Lamp division of the General Electric Company, have been elected to the new office of honorary vice president which was created by the directors of the General Electric Company at their meeting on July 6. All three are directors of the company and will continue to function as such, and will retain their association with the several departments of the company's activities with which they have been so closely identified. Their new title is conferred on them in recognition of their long and valuable services to the company.

* * *

F. E. Vigor has been appointed assistant works manager of the Ashland, Ky., division of the American Rolling Mill Company, Middletown, Ohio. Mr. Vigor has been with the company 18 years and lately has been assistant traffic manager.

* * *

T. W. Frech, manager of the incandescent lamp department of the General Electric Company, was elected to the position of vice president in charge of the incandescent lamp department, and Dr. W. R. Whitney, director of the research laboratory, was elected a vice president of the company and director of research.

* * *

W. C. Goodwin, formerly section engineer of the control engineering department, has been appointed manager of the renewal parts engineering department of the Westinghouse Electric & Mfg. Company. Mr. Goodwin is a member of the American Institute of electrical engineers and was secretary of the Pittsburgh section of that organization, and is also a member of the Engineering Society of Western Pennsylvania.

* * *

Mr. John D. Tinsman, formerly superintendent of maintenance of Wheeling Steel Corporation, at Steubenville, Ohio, has been appointed superintendent of the Republic Iron & Steel Company, Youngstown, Ohio, covering the Youngstown district of that company, excluding the Trumbull works. Mr. Tinsman entered upon his new duties on July 1, 1928.

* * *

Douglas E. Price, formerly with the contracting department of The Koppers Construction Company, has been transferred to the American Tar Products Company in the capacity of contract manager.

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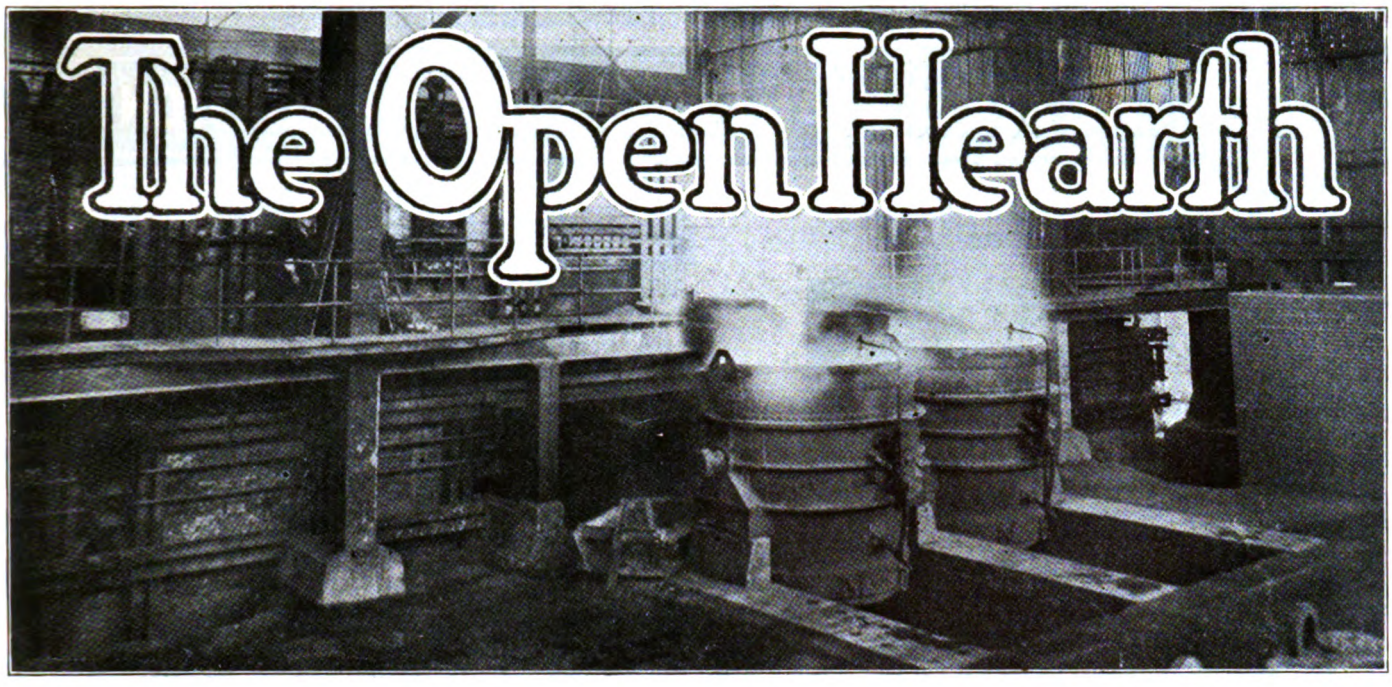

E. H. Gerberding, of Pittsburgh, has been promoted to the position of assistant treasurer of the Westinghouse Electric & Mfg. Company, according to an announcement by company officials. As a 17-year-old boy he began work in the company's treasury department 28 years ago, and has been continuously employed in the same department since that time.

* * *

Pentecost Mitchell, who has succeeded W. J. Olcott as president of the Oliver Iron Mining Company, will have as his operating assistant LeRoy Salsich, who has been chosen vice president and general manager of the Oliver Company. Mr. Salsich last winter was named assistant to the president. Formerly, he had been assistant district manager with headquarters at Hibbing, Minn. A. Y. Peterson, who has been general superintendent for the Oliver Iron Mining Company, in the Coleraine district on the Mesabi range, has now been named assistant to President Mitchell. These promotions follow the resignation of President W. J. Olcott and Vice President J. H. McLean of the Oliver Iron Mining Company after many years of service on the Mesabi ore ranges for the subsidiary of the United States Steel Corporation.

* * *

John E. Gray has been appointed division freight agent for the American Steel & Wire Company, with his office in Pittsburgh.

* * *

J. Fred Mowat has been made chief engineer of the Illinois Steel Company's Joliet plant. Mr. Mowat has been, successively, steam engineer, master mechanic at the blast furnaces and assistant chief engineer.

* * *

Blake R. Vanleer, assistant professor of mechanical engineering at the University of California, Berkley, has been made secretary of the American Engineering Council. He succeeds A. C. Oliphant, resigned.

* * *

Paul Mackall has been made vice president of the Bethlehem Steel Company in charge of sales, succeeding E. S. Knisely, who has been appointed assistant to the president, H. G. Walton.

W. Scott Thomas, 303 National Exchange Bank Building, Providence, R. I., has been appointed New England representative of the Axmann Sand-Throwing Machine Company, 1883 Columbus Road, N. W., Cleveland.

* * *

William C. Maloney who for the past 10 years has been superintendent of the blooming, bar and guide mills of the Pittsburgh Steel Company at Monessen, Pa., has resigned on account of ill health, effective August 1. Bracken Todd assistant superintendent will succeed Mr. Maloney as superintendent.

* * *

R. F. Schuchardt, electrical engineer with the Edison Commonwealth Company, Chicago, has been elected president of the American Institute of Electrical Engineers.

* * *

Donald MacArthur, vice president of the Seaboard By-Product Coke Company, has, in addition to his present duties, been placed in general charge of the Philadelphia Coke Company, a subsidiary of The Koppers Gas & Coke Company. W. H. Earle, formerly in charge of the New York office of The Koppers Construction Company, will be manager of the new company, R. L. Spatz, formerly a construction engineer of The Koppers Construction Company, assistant manager, and Fred Denig, formerly assistant superintendent of the operating department of The Koppers Construction Company, superintendent. The coke plant now under construction for this company will be placed in operation by February 1, 1929.

William Pestell Dead

Mr. William Pestell, vice president and sales manager of the Riley Stoker Corporation was found dead in his berth as the train was entering New Orleans on the morning of July 15. Since 1914, Mr. Pestell was employed by the Riley Stoker Corporation, first as district manager, then as sales manager, and became vice president in 1927.

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THE STEEL PLANT ROLL TURNER AND DESIGNER

G. A. Hargate

At the Ohio Works of the Carnegie Steel Company, G. A. Hargate is roll designer and superintendent of the roll shop.

Relation of Roll Foundry Methods to Rolling of Commercial Steel

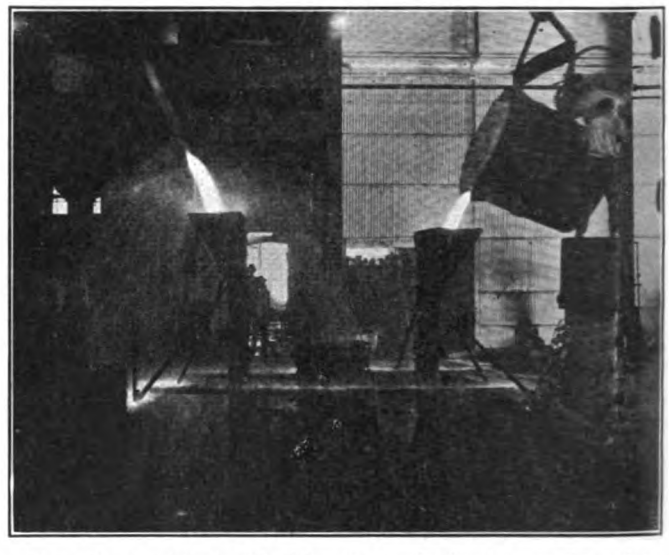
By Walter H. Pfeil*

The manufacture of rolls has undergone a very remarkable revolution in the past 10 or even 15 years, due to the most unusual and exacting tasks required of the many types of rolls in rolling the increased tonnages expected of the modern mill with its varied new alloy steels to be shaped into the demands called for by present day progress.

But a dozen years back, many steel shapes which were considered practically impossible to roll and which have been accomplished today can be fully credited to the unceasing labors of the roll maker in his experimenting with new alloy combinations and heat treatments. To keep abreast of the advancing rolling mill, the roll manufacturer must resort to expert metallurgical supervision, exacting laboratory control, special moulding rigging, selected irons, scrap and alloys, pyrometer controls over melting, annealing and heat treating furnaces and most important of all the individual attention to the work for which the roll is intended in service. Too little thought is being given the latter of these duties in this more important foundry practice, for the making of the roll necessitates a series of close inspections which greatly differ from the general casting theory.

The roll manufacturer in keeping in advance of the rolling mills affords a constant source of new ideas and developments, greatly assisting in the making of better and finer products at a lower cost, even though the cost per pound of rolls has been in some cases materially increased. The bringing about of minimum roll breakage together with the fewer dressings required of scientifically built rolls has greatly reduced the excessive cost of plant maintenance; for it must be remembered that expense does not stop at the inferior product of the roll foundry, but continues with the tie-up of the mill while being torn down for the roll change.

Superior roll products are not attributed alone to the careful analysis of the foundry, but in close co-operation with the consumer. The roll salesman should act as a consultant, combining his efforts of sale with the knowledge of adaptability. The steel manufacturer today has the advantage of the selection of the roll for the purpose. The chilled roll offering him strength for the light gauge plate mill; the heat treated alloy roll the advantage of increased tonnage per dressing and a big item in shape work; then there is the steel, sand and special roll, each offering a service for a service. All told, the application of theory exercised in the making of an advanced roll is magnified two-fold in the output of the mill.



A modern method of inciting the swirl in the pouring of a large chilled roll at Birdsboro.

David W. Chrystie, aged 60, superintendent of the rolling department of the Carnegie Steel Company, Sharon, Pa., died July 23, from a heart attack. He was born in Scotland and had lived in Sharon for more than 40 years.

This page is an open forum for the use of roll designers. If you have articles or notes of interest we would be glad to publish them. Mail them in care of the editor.

*Roll foundry superintendent, Birdsboro Steel Foundry and Machine Company, Birdsboro, Pa.

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THE STEEL PLANT BRICK MASON

Analyze Bauxite and Refractories of High Alumina Content

A study has been made at the Bureau of Standards of the analytical details involved in the analysis of bauxite and burned refractories of high alumina content. The investigation has shown that an accurate analyses of these materials is a far more difficult problem than it is ordinarily regarded. In spite of the fact that the determination of alumina usually is thought to be very simple, extreme values of 54.84 and 56.86 were reported by analysts who co-operated in the analysis of the Bureau's standard sample of bauxite No. 69 (actual Al_2O 55.06 per cent.) The results for alumina and silica reported in the analysis of the standard burned refractories Nos. 77 and 78 were even less satisfactory.

—Brick and Clay Record.

Ceramic Week—1929

American Ceramic Week will be observed from February 4-9, 1929. This same week the American Ceramic Society will hold its thirty-first annual convention at the Stevens Hotel, Chicago.

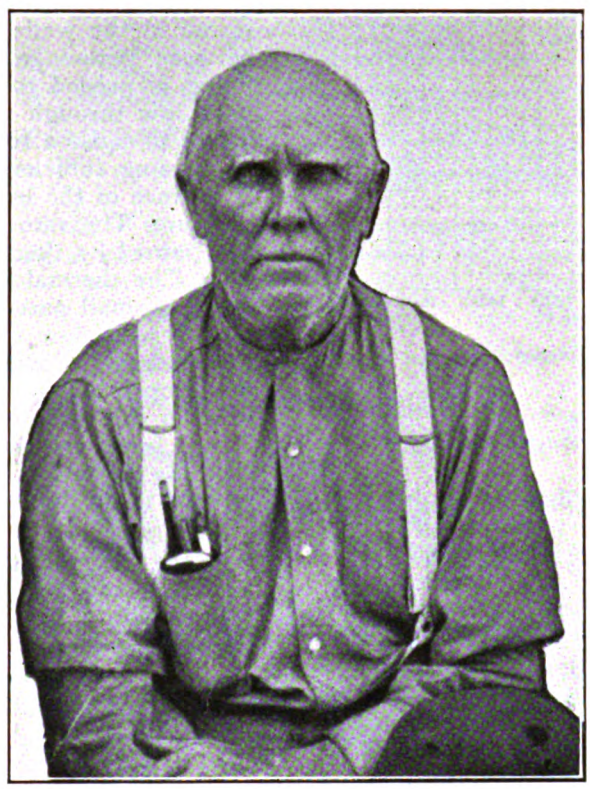
Seaboard Rebuilds

The Seaboard Refractories Company, Perth Amboy, has completed the rebuilding of its plant destroyed by fire some months ago, and has arranged for enlarged output as soon as conditions necessitate. New and modern equipment has been installed.

Expansion of Fire Bricks

Fireclay bricks with a medium or high content of alumina expand only slightly but evenly over the range 20 to 1,300 deg. and then begin to contract. Fireclay bricks with a high content of quartz exhibit the usual irregularities in expansion caused by the various transformations which take place on heating quartz. Magnesite bricks expand considerably but evenly up to 1,500 deg., then begin to contract. Silica bricks of d2.35 retain a constant volume between 600 deg. and 1,600 deg.; those having d2.40 are constant up to 1,450 deg., and those having d2.45 to d2.54 expand considerably up to 1,250 deg. and at 1,600 deg. their total linear expansion is 2.85 to 3.35 per cent of the original length.

—Stahl und Eisen.



Down at the Gulf States Steel Co., M. E. Cushing performs the duties of a brickmason superintendent. He has served at this plant for 19 years.

Vitrefax Company Acquired

A substantial stock interest in the Vitrefrax Corporation, Los Angeles, Cal., manufacturer of fire brick specialties, refractories, etc., has been acquired by the Paraffine Companies, Inc., San Francisco, Cal., which will exercise control of the Vitrefrax organization in the future.

Thermal Conductivity of Refractories

A paper by M. L. Hartmann and O. B. Westmont, entitled, "Methods of Measuring Thermal Conductivity of Insulating and Refractory Materials," was given at the meeting of the American Society for Testing Materials, at Atlantic City. This describes a testing apparatus and methods of determining the thermal conductivity of (1) low-temperature insulating materials, (2) insulation for temperatures up to approximately 2,400 deg. F. and (3) refractory materials. A standard test method is proposed.

Heat Insulation

As a standard by which to judge the value of a substance as an insulator against the flow of heat by conduction it is convenient to take the arbitrary value, $k = 1$. On this basis the thermal resistivities of gases are high:

Carbon dioxide	*k=0.089
Ammonia	0.133
Nitrogen	0.152
Oxygen	0.163
Air	0.165
Hydrogen	9.48

*Comparative values at 32 deg. F.

Air is the only gas which is generally available for use as heat insulation and its thermal characteristic is shown in Fig. 1. Liquids in general are poor heat insulators, for example, for water at 70 deg. F., $k = 4$. The thermal conductivity of none of the solids reach the low value of $k = 1$. Silica is a solid, much used in heat insulation and this substance has an average value of $k = 7$.

Both convection and radiation being flows of heat from (or to) surfaces—the value of k' being fixed by certain conditions—the degree of heat insulation against the flow of heat by these agencies is measured

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by the number of surfaces in series in the path of heat flow.

Thus we arrive at the conception of an ideal physical barrier to the flow of heat consisting of a series of very thin plates of a solid separated by very small spaces of vacuum. These plates would be a solid

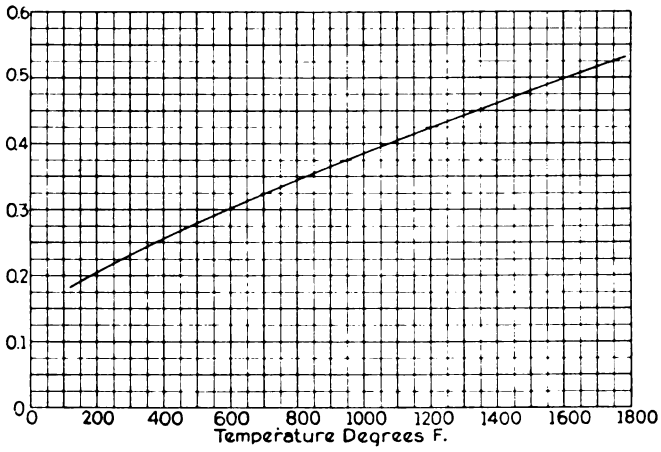

FIG. 1—Thermal characteristic of air.

material of the highest thermal resistivity obtainable, and, being very thin, the heat storage capacity of the barrier would be a minimum.

The first step toward the realization of this heat barrier in a practicable form is to assume that the spaces are filled with air. The introduction of air lowers the heat-insulating value of the barrier due both to the thermal conductivity of air and to the addition of the convection component to the values of k'.

The second step toward bringing this construction of a heat barrier into usable form is to provide cross supporting members between the plates thus obtaining a cellular structure. This gives rise to the fundamental form of all heat insulating materials, i.e., a cellular or porous structure.

Desirable properties of a material for use as heat insulation in the walls of heating chambers (in addition to low thermal conductivity) are:

(a) Low specific gravity.
(b) Low specific heat.
(c) Non-inflammable substance.
(d) Good mechanical strength.
(e) Permanence.
(f) Imperviousness to gases.
(g) Not chemically active with metals.
(h) Easily workable into shapes.

Heat insulating materials are inherently weak structurally and must be supported in a wall structure. To obtain a degree of mechanical strength certain materials are partially burned thus obtaining a degree of vitrification. This lowers the insulating value of the material to the extent that porosity is decreased.

With a heating chamber held at constant temperature the flow of heat through the wall to the surrounding atmosphere is constant. For heating equipment in continuous service the extent to which heat insulation can be used with economy to limit the rate of flow through the wall is the balance between the capital charge on the investment due to the insulation and the value of the heat saved by its use. The saving in heat accomplished by the addition of a given thickness of insulation falls off rapidly as the thickness of the wall of insulation is increased. The investment charge against the insulation increases faster than the heat savings secured by increases in wall thickness.

For heating chambers which are in intermittent service the conditions pertaining to the economies of heat insulation differ because of the loss of heat stored in the walls when the heating chamber cools between periods of use. Assume that a refractory lining is needed to protect the heat insulation. The heat flow through the refractory lining must be sufficient to cause a temperature drop within the refractory lining sufficient to limit the temperature at the inner race of the insulation to its given limiting temperature. The rate of heat flow through the wall is determined by thermal resistance in the path of heat flow. The thermal resistance of the refractory lining is but a small part of the total resistance so that the rate of heat flow through the wall is determined by the thickness of the section of heat insulation. Thus the temperature limitation of the heat insulation fixes its own thickness for a given thickness of refractory lining. Increasing the thickness of the heat insulation to decrease the rate of heat flow requires a corresponding increase in the thickness of the refractory lining.

For furnaces, a refractory—usually fire brick—is required to give strength to the heating chamber structure and also to protect the inner face of the wall section of heat insulation from the heating chamber temperature.

Fire brick, which is the usual refractory lining, has a weight about five times the weight of the heat insulating material. The specific heats of the two materials are of about the same value. The mean temperature of the fire-brick lining, due to its location next to the heating chamber, is much higher than the mean temperature of the heat insulating section of the wall. As a consequence of these conditions, most of the heat stored in a composite wall structure of this kind is stored in the fire-brick section of the wall. Hence, in increasing the thickness of the heat insulation to decrease the rate of heat flow through the wall, the heat-storage capacity of the wall structure is increased at a greater rate.

The total loss of heat from a heating chamber during a given period of time is the sum of the loss through the walls and the loss of heat stored in the wall. As already noted for the continuous operation of a heating chamber over a long period of time, the heat stored in the walls is a comparatively small item in the total loss and can be neglected. For intermittent operation—which is more general in industrial practice—the stored heat loss may be an important item. Under this condition an economic balance between the heat flow through the walls of the heating chamber and the loss of heat stored in the walls is that for a given period of operation these two losses should be equal in amount.

—General Electric Review.

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Production of Fire Brick by Dry Process

In connection with the manufacture of fire brick, recent comment is made in the "British Clayworker" regarding the desire of producers to grind the material to powder and compress it in a power-driven press, but the difficulties experienced have been so great that the use of this method has made little progress. Experiences in different works have led to very contradictory results, and in some cases such small variations make such great differences that comparisons are almost impossible. The chief difficulty is in getting the pressure uniformly distributed throughout the bricks; there are usually soft places in the interior which are due to the fact that powdered clay does not flow uniformly under pressure but has occluded air which, unable to escape, is the cause of the soft places. With a plastic material, on the contrary, no air is occluded in filling the mold and the mass is pressed uniformly.

An increased amount of pressure applied to the powder does not prevent these soft patches, as no matter how great the pressure, the occluded air cannot escape. The addition of grog or crushed quartz will not get rid of all this air, though it reduces the amount left in the bricks. Yet the mixtures of 30 to 50 per cent of clay and 50 to 70 per cent of grog which give such good bricks with a plastic process, yield poor, friable bricks when the almost dry material is pressed. If no grog is present and the clay is finely ground, the resulting dry-pressed bricks are better, so far as soft spots are concerned, but such bricks are so sensitive to sudden changes in temperature and so liable to spalling, as to be almost useless.

In a few works where technical success has been achieved in the manufacture of fire bricks by pressing almost dry material, the cost of production has proved so great as to make the process unprofitable; the output of the presses is low, the power required is excessive, and the wear and tear is much greater than when a plastic or stiff-plastic material is used. If 5 to 6 per cent of water is present, it is much easier to get good results than if a dried material is used, but it is necessary to find the proportion of moisture best fitted to any material. Unless this is done, it may be impossible to get good results.

There appears to be some improved texture formed when a plastic material is pressed, which is not produced when an almost dry powder is used; consequently, while fire bricks can be made from the latter, they are not nearly so good in quality as those made by pressing a plastic or stiff-plastic material. Moreover, when an almost dry material is used, great pressure is needed to produce bricks which can be handled before being burned; this great pressure produces bricks which are too dense to be satisfactory for fire bricks, as the latter require to be porous rather than dense if spalling is to be avoided.

At present, therefore, notwithstanding its apparent advantages and the fact that building bricks can be made by pressing almost dry clay, this process appears to be unsuitable for fire bricks.

—The Ceramic Age.

Fire Clay Products in Denver

Back in 1876 J. O. Bosworth established a wholesale drug business in Denver. Mining was just coming into its own in Colorado at that time and part of Mr. Bosworth's business was made up in the sale of laboratory equipment, mainly crucibles, to miners and assayers. These products were imported from England and brought with them a high cost. Mr. Bosworth wondered if the nearby hills did not possess the materials with which these articles could be made and his wonder led to investigation. Investigation led to discovery. Mr. Bosworth found the rich clay veins near Golden —12 miles from Denver, which have continued to supply the factory all these years. The wholesale drug business was dropped and Mr. Bosworth began the manufacture of laboratory equipment in earnest, calling his concern the Denver Fire Clay Company.

Leading off with crucibles the little firm rapidly began serving the miners far and near. Then followed other assayers equipment such as muffles and scorifiers and the furnaces in which to use them. Having solved the problem of furnishing assayers attention was next directed to mines. One thing led to another; as new needs arose the firm set out to provide them until today the concern serves not only miners but nearly every known industry.

The fire brick manufactured by the Denver Fire Clay Company has passed the most rigid specifications of the United States government. The location of huge clay deposits so near at hand has been of wonderful advantage. The quality of this clay too has played its part. Again fuel is cheap in Colorado hence operating costs to the company have been lessened. Over against these advantages there are the comparatively high freight and express rates against the Denver shipper and it is significant that the products can be shipped everywhere in the face of these rates. Business necessity is responsible for considerable of the growth of the company.

Two factories turn out the fire clay products, two retail stores and two additional offices are charged with the selling and distribution of them.

The factories are modern in every respect. All material is moved with power devices, kilns are fired with fuel oil and automatic control devices are used to the fullest extent. Wet brick are dried in at least 36 hours in specially arranged 100 ft. long tunnels. All through the manufacturing process the clay and the product are tested to assure conformance with specifications. Although most of the work is done by machines certain products require a great amount of hand work.

Present officers of the company are H. O. Bosworth, president; J. Claire Evans, vice president; Ernest R. Harris, secretary; Robert Bosworth, treasurer; and George W. Lindsay, factory superintendent. The board of directors is made up as follows: A. H. Bosworth, George W. Lindsay, H. O. Bosworth, Robert Bosworth, E. R. Harris, and J. C. Evans. J. O. Bosworth, the founder, was killed several years ago in an unfortunate accident during a chemical experiment. His three sons are prominently and actively engaged in the business today.

—Brick and Clay Record.

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SAFETY FIRST IN THE STEEL PLANT

Some Advice

The safety man should not wait for others to suggest the various methods by which accidents may be prevented. He should always be on the alert for any improvement which is practical and will be of benefit. He should study the various operations and equipment of his plant, become familiar with them and thus be able to determine what is needed for the protection of the men.

—National Safety News.

Rules for Living Longer

Eat to live, not live to eat. The stomach is a workroom, not a playhouse.

Don't fail to get plenty of exercise. Walk one or more miles each day.

Keep windows open at night.

Drink lots of water.

Avoid worry and fatigue.

Watch for signs of degenerative disease.

Have a complete physical examination each year or oftener.

—The Prudential Insurance Co. of America.

April Safe in Pennsylvania

April was a comparatively safe month for workmen in the industries of Pennsylvania. The totals of 139 fatal and 10,928 non-fatal accidents reported to the Bureau of Workmen's Compensation during April were the lowest reported for any month in more than five years. The recent concerted drive for safety has had its effect. The proclamation of Governor Fisher, dated March 7, 1928, designating April as "Safety Month," was the first step in the recent accident-prevention campaign.

Is Your Plant Safe?

It is discouraging to find that more than 90 per cent of American employers are doing next to nothing to prevent accidents. A few thousand employers carry on an extensive safety program, but far too many seem to rely upon the operation of workmen's compensation laws and seem satisfied to be fully insured. While this of course is necessary, it will never make factories as safe as they should be.

In plants where safety is considered a high degree of cleanliness is noticeable.

—Industrial and Engineerng Chemistry.

A group of safety first advocates. It is made up of F. L. Wanzer, safety engineer of the Steel Company of Canada, Ltd., his son-in-law and his grandsons.

Essentials of a Safety Program

1—Some qualified person in direct charge of safety work.

2—Clean, orderly and well kept factories.

3—Safe working tools, machines and clothing.

4—Immediate first-aid attention to all minor injuries.

5—Safety instructions from foremen to employees, especially to new men.

6—Proper study, reporting and recording of accidents and their causes.

—From a bulletin issued by General Motors Corp.

Safety Medals Awarded

The E. H. Harriman memorial awards, consisting of gold, silver, and bronze medals and certificates of honorable mention, awarded annually to railroads of the United States by the American Museum of Safety for the most conspicuous organized safety and accident prevention work, were announced for the year ended December 31, 1927, by Arthur Williams, president of the American Museum of Safety, here today. The three medals are first prizes in three groups of class 1 railroads, the classification of the groups being according to the number of locomotive miles operated per year.

The gold medal was awarded to the Union Pacific Railroad as the winner in group A, which consists of those lines operating 10 million or more *locomotive* miles.

The silver medal, first prize in group B, which consists of those lines operating one million to 10 million locomotive miles, was won by the Duluth and Iron Range Railroad.

The bronze medal, first prize in group C, comprised of railroads operating less than one million miles, was awarded to the Texas Mexican Railway.

Publications of Interest

How to Give Artificial Respiration by the Prone Pressure Method," is clearly described in Reprint No. 1203, from the Public Health Reports, issued by the Government Printing Office, Washington, D. C.

"Outdoor Recreation for Employees, *a report published* by the Metropolitan Life Insurance Company, will prove of interest to those in charge of welfare work in our industries.

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